NASA TECHNICAL TRANSLATION NASA TT F 15,870

TRANSMISSIONS OF BLACK-AND-WHITE TV PICTURES OVER COMMUNICATION CHANNELS WITH 1 MHz BANDWIDTH

M. Lange

Translation of: "Die uebertragung von schwarzweiss-fernsehbildern ueber nachrichtenwege mit 1 MHz bandbreite," Fernmeldetechnisches zentralamt, Darmstadt. West Germany, Report FTZ-A-44-TBr-30, August, 1971, 58 pages.

(NASA-TT-F-15870) TRANSMISSIONS OF BLACK AND WHITE TV PICTURES OVER COMMUNICATION CHANNELS WITH 1 MHz BANDWIDTH (Scientific Translation Service) N74-31619

SCL 17B G3/07 Unclas 47731

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 AUGUST 1974

62

1. Report No. NASA TT F 15,870	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle TRANSMISSIONS OF BLACK-AND-WHITE TV PICTURES OVER COMMUNICATION CHANNELS WITH 1 MHz BANDWIDTH		5. Report Date 21 August 1974
		6. Performing Organization Code
7. Author(s) M. Lange		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASw-2483
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes
Translation of: "Die uebertragung von schwarzweiss-fernsehbildern ueber nachrichtenwege mit 1 MHz bandbreite," Fernmeldetechnisches zentralamt, Darmstadt. West Germany, Report FTZ-A-44-TBr-30, August, 1971, 58 pages.

16. Abstract
This paper discusses the possibility of television transmission using a significantly reduced bandwidth which may be of advantage for certain CCTV (closed circuit TV) applications. Problems such as the effective bandwidth requirement of a given TV standard, pulse transmission over a signal challen of limited bandwidth, picture quality, and its determination have been studied. Experiments involving restricted bandwidth transmission of signals using the TV broadcasting standard and using a videophone standard are described. It is concluded that the 1 MHz bandwidth is sufficient for useful Tv transmissions.

PRICES SUBJECT TO CHANGE

17. Key Words (Selected by Author(s))		18. Distribution Statement Unclassified - Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

TRANSMISSIONS OF BLACK-AND-WHITE TV PICTURES OVER COMMUNICATION CHANNELS WITH 1 MHz BANDWIDTH*

M. Lange**

ABSTRACT. This paper discusses the possibilities of television transmission using a significantly reduced bandwidth which may be of advantage in certain CCTV (closed circuit TV) applications. /1b***

Problems such as the effective bandwidth requirement of a given TV standard, the pulse transmission over a signal channel of limited bandwidth, and of picture quality and its determination have been studied.

For a given bandwidth of 1 MHz, two solutions to the problem are presented as a laboratory set-up in a comparison test:

a) restricted bandwidth transmission of signals using the TV broadcasting standard (625 lines/50 Hz), and

b) transmission using a standard which has been proposed for videophone use (267 lines/60 Hz.

Through viewing tests employing a multitude of test pictures and viewers would be required in order to arrive at a final conclusion, the screen photographs presented here lead to the conclusion that 1 MHz bandwidth TV transmissions supply sufficient information to be of practical use for a number of applications.

An appendix deals with problems of changing the horizontal deflection stages of TV monitors to a line frequency of 8 kHz and discusses a case of practical application (TV traffic control at Hanover).

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*Technical report of the FTZ (Technical Telephone Authority) Research Institute. No. A-44. Partial report TBr-30, August, 1971.

**German Post Office. FTZ. Research Group: D-21.

***Numbers in the margin indicate pagination of original foreign text.

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1. Introduction

1.1. General Remarks

About 220,000,000 TV receivers are being operated at this time. About 90% of them operate according to TV standards with line frequencies around 15 kHz and image change numbers of 25 or 30 Hz. The video bandwidth corresponding to this is about 5 MHz. The rest include receivers which use the old European 405 or 819 line norms. Except for special installations, such as those for space flight, the so-called industrial TV installations (CCTV) use similar standards. Under these conditions, it seems appropriate to consider other TV systems, especially since it is known that the present day assumptions which have led to the standards used today are not changing. In practice, it is impossible to store an entire picture and it is necessary to use the cathode beam tube for converting the electrical signals into optical signals. These do not have a favorable optical behavior and, therefore, there is a requirement for the relatively high image change frequencies, which would not be necessary for motion information. Even though work is being done in many places on image storage devices and new image reproduction devices, these cannot be considered in this paper because they are not yet commercially available. /4

1.2. Problem Formulation

Industrial television, or more precisely, non-commercial television, has experienced an enormous growth in parallel with the development of entertainment television. More and more applications are being developed for which it is necessary to transmit a television picture through a radio signal. For example, the TV camera must be mobile (example, transmission of images of the traffic situation from helicopters). The difficulties associated with frequency allotments were already evident when the voice radio channels were assigned (oebL and noebL). Therefore, because of the high bandwidth requirements for television, it is not possible to assign frequencies for this purpose. Therefore, it is very necessary to transmit the desired information using a small bandwidth with a reasonable amount of effort. /5

On the other hand, the transmission of non-commercial television pictures within cities is related to the problem of laying new cables. Therefore, it was natural to attempt to find new ways of transmitting the television signal over normal telephone lines.

Even though, at the beginning of the work, we were not able to determine the frequency bandwidth which should be considered, during the work we were able to find that a bandwidth of 1 MHz represents a meaningful target. A reduction of the video bandwidth by a factor of 5 is required for high frequency transmissions, if one wishes to have an appreciable reduction in the bandwidth requirement of the HF installations. This is because of the finite edge inclination of the transmission channels. On the other hand, the work on the development of the videophone showed that a frequency of 1 MHz can be controlled as far as attenuation and crosstalk are concerned in available symmetric cables of local telephone networks.

The developments in the area of videophones also indicated that when the problem was being solved, one should not only consider systems with 625 lines and 25 complete pictures/seconds, but also scanning systems designed for videophones.

2. Scanning Standard and Bandwidth /6

2.1. Optimum Scanning Standard for a Given Bandwidth

If one is completely free in the selection of the scanning standard, then for given bandwidths, the optimum line number is approximately given by the relationship

$$\boxed{z = \sqrt{\frac{2f_o}{b \cdot a \cdot K}}} \qquad (1)$$

Here we have z = line number, f_0 = upper limiting frequency of video channel, b = number of complete images transmitted per second, a = ratio of image bandwidth to image height (4:3 for conventional image tubes). K is an empirically determined factor which we will discuss below. The equation is only approximate because it does not consider the times required for line and image return. If we substitute the values $f_0 = 10^6$ Hz, b = 25 Hz, a = 4:3, and K = 0.65, the result is approximately 300 lines. This is not very far from the old British 405 line standard. It may be appropriate to mention that, even though this standard has been given up, at the present time, over 10,000,000 TV receivers are operating on this standard and, apparently, to the satisfaction of their owners.

For an image change frequency of 30/seconds, we find that the line number is approximately 270. When the line number is finally specified, it is not necessary to only consider the return times, but also realistic divider conditions must be found for the tact generator.

2.2. Bandwidth Requirement for Given Scanning Standard

The discussion in the preceding section assumes that the substituted value of K is correct. In the following, we will discuss the range over which this factor can vary. The related questions have been intensely debated up to the introduction of wireless TV [2, 3, 4], but mostly on the basis of theoretical /7
analysis.

2.2.1. Kell factor

If one attempts to determine the bandwidth requirement for a given television system, one usually starts with the so-called checkerboard frequency. It is assumed that black and white image fields follow each other in the line direction, the so-called image points, and in the vertical direction the lines are separated by the dark intermediate spaces. With this assumption, we find that the checkerboard frequency is

$$\boxed{f_s = \frac{1}{2} \cdot z^2 \cdot a \cdot b \cdot \frac{1-p}{1-m}} \qquad (2)$$

m is the percentage of the line duration which is occupied by the line return duration and p is the percentage of the image duration which is occupied by the image return duration. The relative return duration can be referred to a partial image or to a complete image.

If we now substitute the usual values of radio standards in Equation (2), we find f_s = 7.5 MHz. Kell and his coworkers [5] found, in 1934, that the ideal concept which is the basis of the checkerboard frequency does not apply in reality. The resolution in the vertical direction is poorer than one would first assume. When wedge-shaped line bundles oriented towards each other are reproduced over a system with a checkerboard bandwidth, it is found that these are much more poorly resolved with respect to positions parallel to the line direction than in positions perpendicular to the lines (rotation of the image by 90° in the image field). Since it is generally accepted that the resolution should be about the same in all directions, therefore, the upper frequency limits can be much lower than the checkerboard frequency. The reduction factor is named after Kell and was indicated to be 0.65. Corresponding to this, we have the video frequency of 5 MHz for the 625 line system in use today.

The experiments of Kell were very useful during a time it was believed that the bandwidth requirement for television would be enormous. Today, such a problem would be clarified by statistical experiments with unbiased observers using strictly defined viewing conditions which are close to practice. The observation distance (see Figure 7) is very important here. Such a subjective evaluation test which would have to be carried out with a transmission system and which would have to resolve the frequency of 7.5 MHz perfectly, from the picture specimen to the image appearing on the image screen and at 625 lines, 25 images/sec, would probably result in no noticeable deterioration of image quality for a large number of average test images. This would be the case if the upper limit of the video frequency band would be reduced from 7.5 to 5 MHz. The question of how much this upper frequency limit can be further reduced until there is a perceptible decrease in the picture quality remains open. (All new image quality investigations in recent times assume a certain scan standard for a specified f_0.) /8

Even though according to the original definition, it would not permissible, in the following we will mean by the Kell factor the ratio of the upper video frequency of a certain system and its checkerboard frequency. Figure 1 shows the data which are important for the frequency bandwidths for a few of the most important television systems, as well as the checkerboard frequency and the Kell factor.

When television systems are evaluated, one must always consider that the resolution capacity of the human eye is limited. Its behavior can be interpreted using a model, which amounts to a lowpass filter. Such a representation has been /9 taken from a paper by Sadashige [6]. This is given in Figure 7. One can see the very great importance of the relative observation distance, which is a parameter here. In addition, it is possible to estimate from the curves and for a certain system (525 lines/60 Hz here), how a change in the bandwidth affects the image impression.

2.2.2. The influence of the line jump method

It is certain that the cathode ray tube can only be used as an image reproduction device using the line jump method. This is caused by the unfavorable decay characteristics of the available luminous materials. An ideal luminous material would have to have an approximately rectangular decay characteristic, and that of available luminous materials is essentially exponential. It is also known that, by introducing the line jump method, a further deterioration of the resolution in the vertical direction is produced. The perturbation effects related to the line jump — intermediate line flickering, line migration, and pair formation of lines — together lead to a very noticeable deterioration of the resolution in the vertical direction under some conditions [7]. If we assume that the resolutions in the horizontal

Television system =	CCIR Characteristic	Format width/height	Lines per complete picture	Vertical frequency*	Horizontal frequency	Checkerboard frequency	Video bandwidth	(Video) Kell factor
				Hz	Hz	Hz	Hz	
Radio, France**	E	4:3	819	50	20 475	13	10	0,77
Radio, Belgium	F	4:3	819	50	20 475	13	5	0,385
" , W. Germany	B	4:3	625	50	15 625	7,5	5	0,67
" , USA	M	4:3	525	60	15 750	6,45	4,2	0,65
" , Great Britain**	A	4:3	405	50	10 125	3,25	3,0	0,925
Industrial TV***	—	4:3	267	~60	8 000	1,66	1,0	0,6
Videophone****	—	11:10	267	~60	8 000	1,37	1,0	0,73

*All systems with line jump.

**Conversion to 625 lines is in process.

***Test system

****Normalization suggestion of the Siemens A G.

*****Commas in numbers indicate decimal points.

Figure 1. Television standards.*****

direction are to be about equal to those in the vertical direction, then we would be justified in further reducing the upper video frequency for a system having a given line number. The perturbation effects caused by the line jump cannot be treated in detail in this paper. We would like to point out that the intermediate line flickering at 30 complete pictures per second decreases noticeably and that the other perturbation effects for systems with relatively low line number are apparently less disturbing than for systems having a high line number.

2.3. Practical Experience with Reduced Bandwidth

According to what has been said, one should not be astonished that, in the area of entertainment television and also so-called semiprofessional television, there are a number of examples which would indicate that satisfactory image reproduction could be obtained with substantially reduced bandwidths, compared with the nominal system bandwidths. S. Deutsch in a paper [8] indicated that the bandwidth of conventional US American home receivers often is only slightly above 2 MHz, which has been confirmed by other authors [9]. It is understandable and probably economically reasonable that the effective bandwidth of the image shown on the screen of a home receiver is much lower than, for example, on the monitor at the final checkpoint in a studio. The experience with the first semiprofessional video recorders was very interesting. These devices, which offer the possibility of image recording on magnetic tape at a relatively modest cost, have bandwidths which are still below 2 MHz. In spite of this, it is not only possible to obtain useful entertainment programs with them, but also images which justify the use of such devices in commercial applications. Apparently, the criteria used for the evaluation of industrial television pictures are different from those used for entertainment television. In the first case, esthetic considerations are the most important. In the case of industrial television, we are only interested in the transmission of information in image form. The image quality only has to be good enough so that the information required will be transmitted with a certain certainty.

2.4. Methods for Subsequent Enhancement of the Subjective Image Sharpness

Sometimes the resolution losses connected with the transmission of a television image through a limited bandwidth channel are considerable. Therefore, very early methods were sought to at least partially equalize these losses. The best known method is called "crispening" and follows a suggestion of Goldmark [10]. In this method, additional signals are added to the television picture and these signals are obtained by differentiation of the original signal. This leads to an increase in the steepness of the bright-dark transitions. This means that the subjective image sharpness can be enlarged again. However, image details which have been lost cannot be added again; contrast losses remain (see Photograph 5.1). In addition, when there is extreme band clipping, transitions which originally should not have been sharp become even sharper. This is a natural limitation of the method. In practice, this method has only been applied in certain special commercial units such as, for example, standard converters. /11

3. Solutions

3.1. Transmission According to the Radio Standard with 1MHz Bandwidth

Considering the ideas presented in Section 2, it seems appropriate to carry out tests according to the 625 line standard with greatly reduced bandwidths. Such experiments were therefore made at the Research Institute of the FTZ (Telephone Technical Central Office) [11]. However, they have not resulted in definite conclusions because special calculated filters were used for clipping the frequency band which had an optimum pulse output. In the final analysis, they amount to Thomson filters. In practice, it is impossible to have such characteristics in a communication channel which bridges a large distance. We will discuss this later on. In addition, handwriting samples were used for evaluating the band-limited images. We must consider the fact that small handwriting is not always transmitted in a satisfactory manner in a 625 line system even for complete resolution.

In the meantime, it has been shown many times that, for /12
example, for transmitting a typewriter page DIN A 4 in approximately natural size, it is necessary to use a system with at least 1000 lines and a video bandwidth of 20 MHz (for conventional image change numbers) [12, 13]. Therefore, the experiments confirmed our belief that the image impression of critical image samples would deteriorate considerably when the bandwidth was reduced.

Results from the Institute for Radio Technology in connection with other experiments were much more interesting. Investigations in 1968 [14] showed that black and white television pictures when limited to a bandwidth of 2.5 MHz were only evaluated to be "worse" by 60% of six technicians, and 40% of them evaluated them as "less poor" than images with the full bandwidth. It is natural that this evaluation was carried out according to standards for entertainment television. Therefore, we can expect that for simple information transmission, a further deterioration would be acceptable, so that bandwidths below 2.5 MHz would still result in useful results.

3.2. Selection of a Different Scanning System

In Section 2.1, we already indicated that, for a bandwidth of only 1 MHz, the 625 line standard is not the most suitable. Therefore, one must consider using a different number of lines. However, this idea was always opposed by the statement that, in this way, it would be necessary to have a special system with special devices, which would make the units much more expensive and compared with the mass produced entertainment television devices, the costs would be so high that they simply could not be used. Therefore, no one was prepared to even consider a different scanning system. However, we will show that the modifications to mass produced devices are relatively minor and that the additional costs will hardly have an effect.

3.3. Scanning Systems of the Videophones /13

Any system which deviates from the usual standard must have its own cadence generator which is only suitable for it. Therefore, it would be advantageous if one could use a different system. Such systems have been developed in the meantime for videophones, which operate at a bandwidth of about 1 MHz and for which a standard is now being discussed which has an image change frequency of about 38 Hz, and with a line frequency of exactly 8 kHz, it is possible to have an image with 267 lines. The videophones take advantage of factors which are the result of using the upright image size or an approximately square format (see Figure 1). When used in industrial television, the usual 4:3 image format should be used. This does not influence the cadence generator.

When broadcast television was introduced, the cadence generator represented a very complicated and expensive device. Significant improvements have become possible by modern technology. In the case of the American Picturephone[R] II, the entire cadence generator consists of a single integrated circuit [15]. In the first samples of the Siemens videophone, the entire cadence generator was built on a single circuit card using TTL building blocks. The Siemens AG made available to us two cadence generator cards, for both 289 lines and 25 complete images/second as well as one for a new suggested standard with a line frequency of 8 kHz and about 30 image changes/second. Therefore, we were in the position of carrying out transmission tests for industrial television at bandwidths around 1 MHz, using a special scanning system.

4. Pulse Transmission in a Band-Limited Communication Channel

The variation of a signal which is obtained at the output of a communication channel with approximately rectangular transmission curve and which represents the response to a very steep pulse at the input is described by systems theory [16]. We will /14 not discuss the details here. We would only like to remind the reader that the rise time τ of the response to a very steep pulse at the input is related to the limiting frequency f_g of the channel in the following way:

$$\boxed{\tau = \frac{1}{2 \cdot f_g}} \qquad (3)$$

An overshoot occurs which is almost 10% for optimum phase conditions. For a conventional system with minimal-phase behavior without delay equalization, this can amount to up to 20%, and then only additional oscillations occur. When a television image, which essentially has the characteristics of a pulse, is transmitted, it is necessary to have an approximately distortion-free transmission of the pulses. Overshoot will be more disturbing, the greater the period duration of its wave nature is compared to the image point duration.

If one reduces the bandwidth of a system considerably, one would expect considerable disturbances because of pulse distortions. If band limitations are made using steep lowpass filters and if there are no special equalization measures for limiting frequencies below 2 MHz, the disturbances caused by overshoot are so bad that the images on the image screen can no longer be used.

A detailed study has investigated the question [17] of the conditions for which pulses can be transmitted with low distortion and for a given bandwidth. N. W. Lewis has applied the results of this work to television [18]. In the following, we will discuss the consequences of this work.

4.1. The Concept of Pulse Bandwidth

If a very narrow rectangular signal of duration τ_p is applied to the input of a band-limited transmission path, then the pulse bandwidth f_p can be defined as follows /15

$$\boxed{f_p = \frac{1}{2\tau_p}} \tag{4}$$

If the transmission system with approximately rectangular transmission characteristics itself has a limiting frequency f_0 and if $f_0 = f_p$, then a signal will appear at the output whose maximum amplitude is 0.8727 times [$2/\pi \cdot Si(\pi/2)$ exactly] the input amplitude. Also, a considerable overshoot will occur. If the limiting frequency is selected as $f_0 > f_p$, then, as f_0 increases, the step response will approach the input signal more and more. The advantage of this type of definition is that it is possible to assign this bandwidth to an arbitrary transmission quadropole, which transmits a pulse having a given pulse bandwidth with certain distortions.

4.2. Definition of the Window Bandwidth

In conventional communication technology, it is customary to define the limiting frequency as that frequency at which the transmission decreases by 3 dB. This is not suitable for pulse transmissions. In addition to the pulse bandwidth already defined, we are more interested in the entire range in which frequencies can be transmitted. Schuessler and his coworkers have selected a frequency for this at which the amplitude has dropped to 40 dB. Such a definition is appropriate because, in the case of transmission characteristics which follow the

Gaussian or Thomson variation, we can establish that the transmission of spectral components with amplitudes below 40 dB is not important for the pulse reproduction. Since practical transmission systems, for example a tertiary group of a multi-band telephone system, have approximately rectangular transmission characteristics, one must assume that this bandwidth is the window bandwidth. /16

4.3. Optimization of Pulse Transmission

If we start with the fact that during pulse transmissions, unacceptably high distortions will occur when the pulse bandwidth equals the window bandwidth, apparently here we are concerned with the question of finding the pulse bandwidth for which allowable distortions of transmission occur for a given window bandwidth. It is already assumed that optimum delay equalization has been carried out.

First of all, we must clarify the question of the allowable distortions. First of all, we are concerned with the overshoot. We can refer to an American paper [19]. The results of this paper agree, essentially, with our own experience. According to this, the first overshoot does not disturb us that much, but the first undershoot is very detrimental. For satisfactory transmission, it cannot exceed a value of 2%. This means that the ratio of the pulse bandwidth and window bandwidth must be selected so that the overshoot does not exceed 2%.

In the case of entertainment television with a bandwidth of 5 MHz (= window bandwidth), the pulse bandwidth for completely distortionless transmission is only 2.5 MHz, because a jump with a rise time of $\tau_s = 1/2f_0 = 100$ ns can only be transmitted with considerable distortions. Even though these distortions can hardly be noticed on conventional image reproduction devices because of their short period, in communication technology, they have for a long time been the source of confusion. They have also been responsible for the fact that many transmission systems, for example directional systems, have much greater window bandwidths than 5 MHz.

If we compare the work of Schuessler and his coworkers with the possibilities of using a combination of a Thomson filter and a lowpass, we can see that the optimum pulse reproduction of the transmission channel can be well approximated by a combination of a lowpass and a Thomson filter. Therefore, the use of even more complicated and expensive filter installations, which would be difficult to obtain with communication paths, does not seem justified. An additional improvement in the ratio of rise time and overshoot is not possible, unless the crispening technique is used. /17

Basically, the optimum pulse formation becomes more important as the band clipping increases.

5. Problems of Image Quality

The image quality of television can only be evaluated by subjective image observations by a large number of observers with a large number of average picture samples. The result obtained is in the form of statistical data (average, scatter). Therefore, there is a tendency to use absolute criteria instead of subjective criteria, such as for example, to use pulse response or other measurement results. The relationship between these measurement techniques and subjective image impressions is not conclusive in all cases and has not yet been established [20].

5.1. Image Quality for Broadcast Television

If we consider the subjective image quality observations and if we have specified a few basic assumptions such as the observer distance, contrast and brightness of the image being observed, surrounding field illumination, etc., the question still remains of establishing the criteria according to which the image quality is to be evaluated. In the case of entertainment television, which primarily transmits artistic images, the esthetic impression of the observer will be the criterion. /18
The image quality will still be great if the image not only greatly corresponds to the original image which is available for comparison, but also when it is found to be "beautiful" or "pleasant." A certain standard for this is a movie picture.

5.2. Image Quality and Information

It is natural to suspect that there are relationships between image quality and transmitted information. From entertainment television it is known that relatively poor image quality is acceptable to the television viewers when the program being watched is especially exciting or moving. If we now consider industrial television, it becomes clear that only an esthetic evaluation of the image quality is no longer sufficient. The industrial television installation is supposed to transmit certain information, for example, traffic flow through a door, occupation of a parking area, etc. This information can be reliably obtained even if the image quality is restricted. The type and extent of the transmitted information will determine the image quality which is acceptable for a certain application. If we investigate the suitability of a new television system or a greatly modified conventional television system for such applications, the criteria used in broadcast television for image quality will not be sufficient. It will be necessary to develop special criteria from practical experience with applications. In this part of the paper, it was not possible to deal with this subject. We would like to point out that the results presented here must be supported by investigations of this topic.

5.3. Interaction of Various Influences on the Image Quality

Because of the problem posed, we may expect that, first of all, it is debatable whether the image quality is compromised by reducing the resolution. The image quality is also influenced by other factors, such as the noise separation, gradation distortions and geometric distortions, etc.

The state of the art regarding the influence of several simultaneous detrimental factors for a television picture is not yet satisfactory. Extensive work has been carried out by the British Post Office Authority [21], and we may summarize these results as follows: if we express the deterioration experienced by a television picture because of a certain type of disturbance in certain units (for example, in "imp," impairment unit), then according to data of the British scientists, if there are several disturbing effects, the total image quality can be found by simple addition of the impairment units from the various disturbing sources. If we accept this theory, it follows that, if all of the possible impairments occur with about the same magnitude, that is moderate noise separation, visible gradation distortions, visible geometric distortions, and noticeably reduced resolution, it is necessary that all of these effects only occur in a very limited way if the total image quality is not to drop below a certain prescribed level. This situation occurs for broadcast television.

Conversely, it follows that when one impairment is allowed to become especially large, for example if the resolution is reduced very drastically, very high requirements must be attached to the other parameters. The high image quality which was produced by the first videorecorders and which was not expected, can in part be explained by the fact that there was a relatively good noise separation at the output signal and there were practically no gradation distortions.

For the 1 MHz transmission, this means that the noise separation should be as great as possible and the gradation transmission should be exceptional. This should not be difficult for small bandwidths. When evaluating the results given in this report, one must consider the fact that the images do not have any noticeable shot noise, and there was a good reproduction of the gradation, as the gray wedges shown indicate.

6. Test Installation

The devices used for carrying out the experiments were assigned to two groups: (see Figure 6):

a) a group for the simulation of band-limited transmission channels;

b) a group consisting of units which are necessary for producing and reproducing television pictures according to the 267 line method.

6.1. Simulation of Band-Limited Transmission Channels

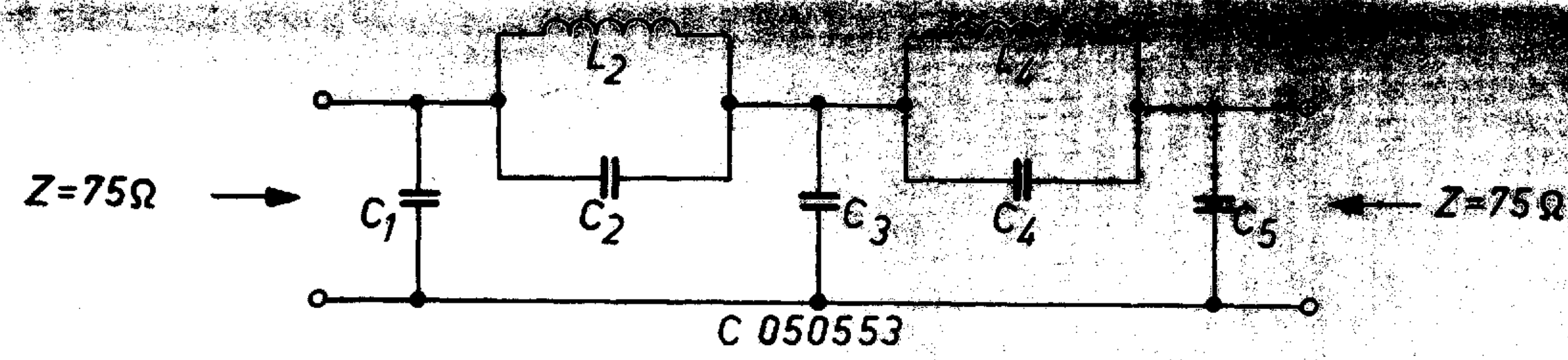
Since we assume that the transmission channel essentially has no nonlinear distortions and a very good noise separation, it is sufficient to simulate its amplitude variation and possibly its phase variation. Suitable lowpass filters can be used for this which are equipped with a delay equalization. There are also the corresponding Thomson filters for pulse shaping and, finally, there are separation amplifiers.

6.1.1. Lowpass filters

Cauer lowpass filters from the Telefunken filter catalog [22] were selected as lowpass filters. In order to hold down the costs, we selected fifth order filters. Since the filters, in general, are operated with short lines between real connections, we could accept a relatively large reflection factor, so that there resulted a filter with a relatively high edge inclination. We selected type C-050553. Corresponding to the /21 tests, which had been previously designed somewhat differently with band-reduced 625 line signals, we calculated band filters for a total of nine different bandwidths and constructed these. The table (Figure 2) gives the data for those filters which were used in the experiments described below. The lowpass filters approximated the data given in the catalog very well after matching the pole frequencies.

6.1.2. Delay equalization

Sufficient delay equalization was one of the basic assumptions for a successful execution of the experiments. Of all of the measures for reducing the overshoot to an acceptable level, delay equalization is the most effective, primarily because it has no other disadvantages associated with it. However, delay equalizers are very gladly avoided because of the associated dimensioning problems. According to experience obtained in earlier work and published elsewhere [23], we found that, for pulse transmission, it is not so important to have a



Lowpass	f_0 *)	f_4	f_2	L_2	L_4	C_1	C_2	C_3	C_4	C_5
	MHz	MHz	MHz	μH	μH	pF	pF	pF	pF	pF
B	2,47	2,75	3,94	5,61	2,77	554	287	1.163	1.177	159
D	1,63	1,83	2,61	8,43	4,16	799	413	1.675	1.695	231
H	1,0	1,10	1,67	14,0	7,10	1387	718	2.920	2.948	710

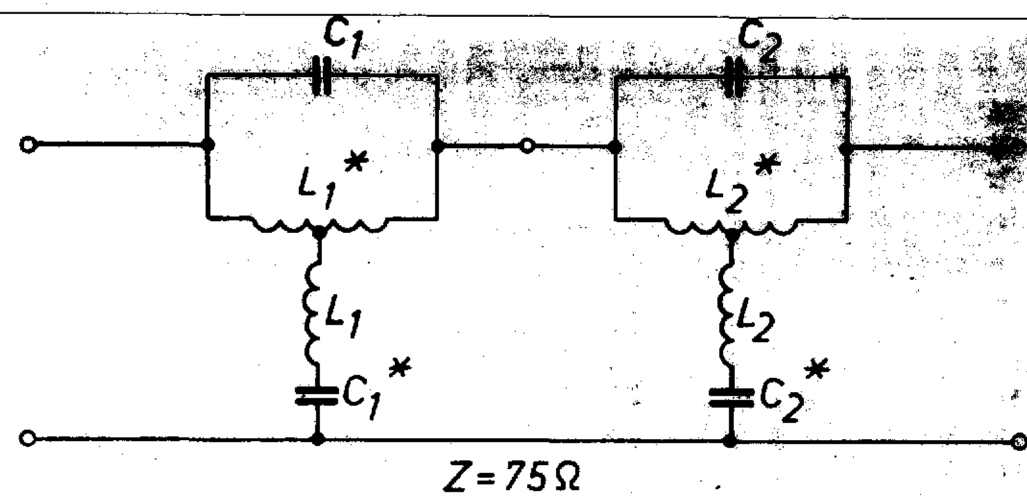
*Measured frequency (including delay equalizers) for 6 dB operational attenuation.
**Commas in numbers indicate decimal points.

Figure 2. Lowpass filter for television transmissions with reduced bandwidth.**

certain delay tolerance but rather, it is necessary to have an optimum dimensioning with respect to the pulse reproduction. As a consequence of this, it follows that an approximately uniform distribution of the overshoot among pre-oscillation and post-oscillation can be carried out with a relatively small amount of effort. We were able to obtain the assistance of the FGr D 11 (specialist group) for the dimensioning of the delay equalizer. The experience in this connection has been reported in the meantime in a technical report [24]. It also contains oscillograph photographs of the transient processes of the low-pass filters without delay equalization. It was possible to achieve considerable optimization of the transient process using only two all-pass members (Figure 3).

6.1.3. Thomson filters

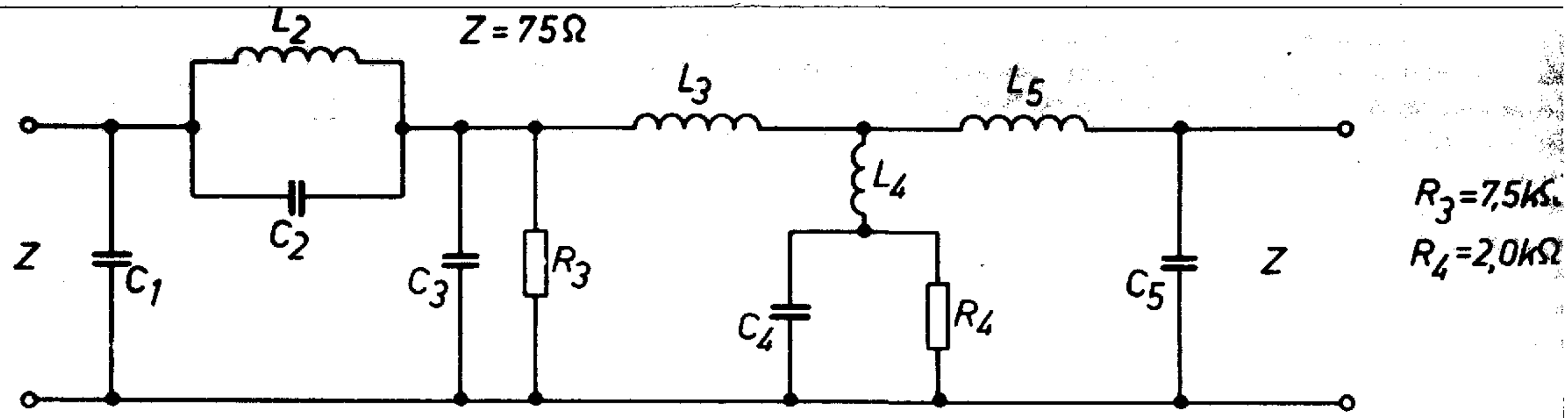
A suitable Thomson filter was built for each lowpass filter. Together with the lowpass filter, this resulted in a transmission characteristic for which the pulse response had an overshoot of about 2%. For this, the first blockage pole of the lowpass filter was substituted at the limiting frequency of the window bandwidth and we assumed a f_p/f_0 factor of 0.8. The filter itself is based on the dimensioning of Thomson [25] in an improved version, as given in a publication of McDiarmid [26]. The calculated rise times could be maintained well with the filters we built. The essential disadvantage of the filters indicated by Thomson is that they are difficult to match. For this reason, we developed a few high quality transistorized separation amplifiers, which were fixed at an amplification factor of 1:1 and which had an extremely good input and output matching. In this way, it was possible to isolate the Thomson filters from the other units in the transmission chain. The filters used in the following experiments are also given in the table (Figure 4). /22



Delay equal- izer for lowpass	L_1	L_1^*	C_1	C_1^*	f_1	L_2	L_2^*	C_2	C_2^*	f_2
	μH	μH	nF	nF	MHz	μH	μH	nF	nF	MHz
B	3,54	40,9	0,629	7,28	0,992	3,99	11,9	0,709	2,11	1,735
D	4,86	60,4	0,862	10,75	0,697	5,78	19,2	1,03	3,41	1,[illegible]
H	10,08	108,4	1,79	19,27	0,361	11,77	26,06	2,09	4,63	0,681

*Commas in numbers indicate decimal points.

Figure 3. Delay equalizer for TV transmissions with reduced bandwidth.*



	τ	f_p	f_4	C_1	C_2	C_3	C_4	C_5	L_2	L_3	L_4	L_5
	µs	MHz	MHz	pF	pF	pF	pF	pF	µH	µH	µH	µH
B	0,23	2,2	4,51	103,5	108	772	2.959	272	2,15	4,22	0,421	4,14
D	0,34	1,47	3,01	155	162	1.158	4.435	341	3,26	6,33	0,632	6,21
E	0,40	1,26	2,57	182	189	1.354	5.185	397	3,78	7,39	0,738	7,26
H	0,57	0,88	1,81	259	270	1.929	7.387	566	5,49	10,52	1,051	10,34
								Q_{min} =	70	100	50	100

Tolerances: $L_{2\,u.5}$: ±1%, $C_{3,4}$ = ±0,5%
$C_{1,2,5}$: ±2%

*Commas in numbers indicate decimal points.

Figure 4. Thomson filter for TV transmissions with reduced bandwidth.*

6.1.4. Crispening amplifiers

In order to evaluate the improvement possibilities using the crispening technique for very highly band-limited signals with 625 lines, we built a crispening amplifier which is based on a circuit diagram suggested by H. Wendt and which is completely transistorized. A block diagram of the amplifier is shown in Figure 5. The time constants of the differentiation units were made variable in order to process different input rise times. Experiments showed that the rise time can be about cut in half using the crispening technique at an acceptable level of overshoot, which certainly corresponds to a considerable increase in the edge sharpness. On the other hand, from the oscillograms of the $\sin^2$ pulses, it can be found that, if a contrast reduction because of resolution losses has occurred, it cannot be reversed by crispening. This is also true for image details which are completely lost because of deficient resolution.

6.2. Image Recording and Reproduction Devices

In order to make a comparison of band-limited 625 line signals and another, low line television system, it was important to have available approximately the same type of units. We were fortunate that this requirement could be satisfied.

6.2.1. Cadence generator

A studio cadence generator of Fernseh-GmbH was available for the image transmission at 625 lines/25 images/second.

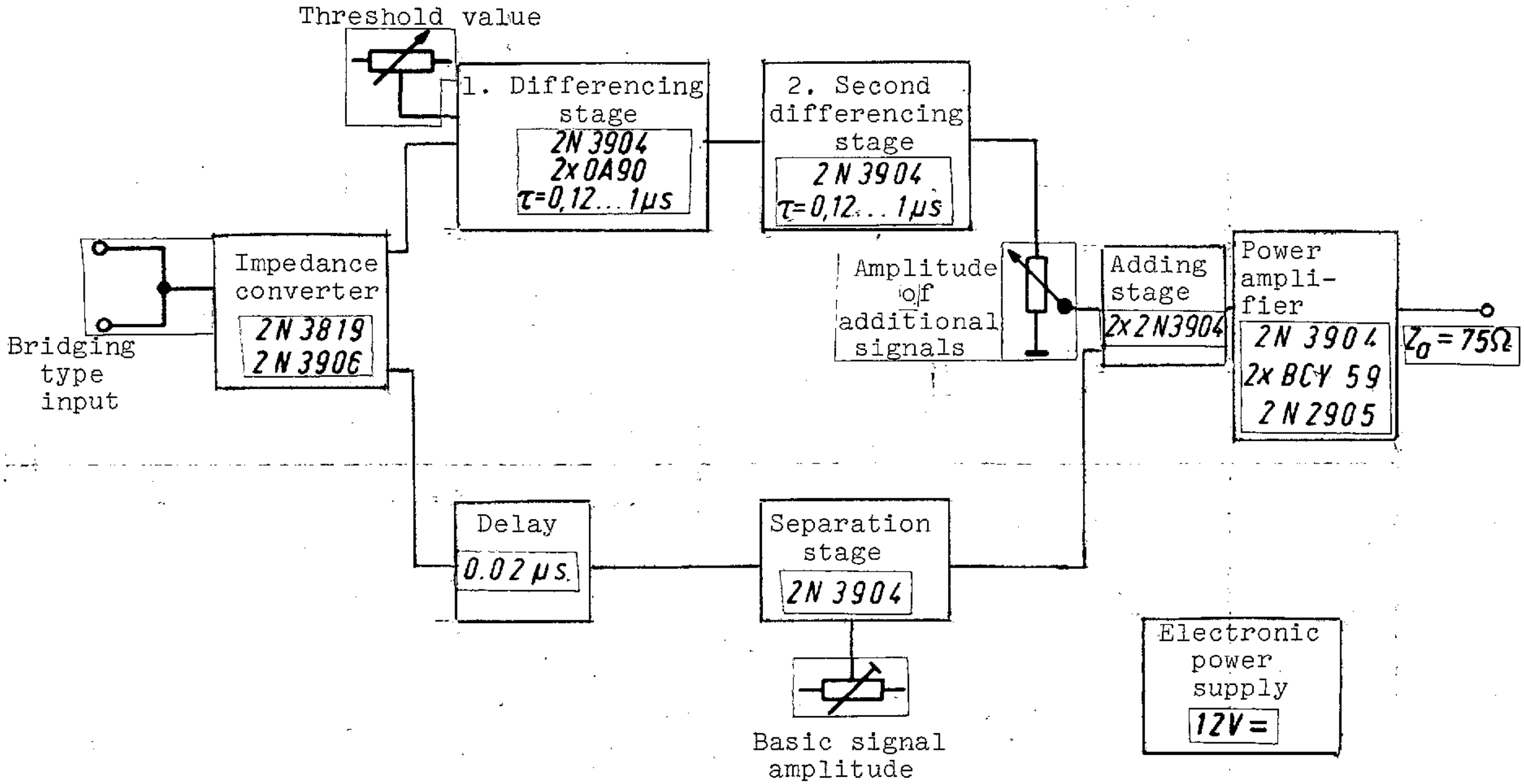


Figure 5. Crisepning amplifier, block diagram.

As already mentioned, we were able to use cadence generator units of the Siemens AG for our experiments with low line television systems. The units were made into a device by adding separation amplifiers and a power supply. It could be operated just like a studio cadence generator, i.e., 75 ohm output for A, S, V, and H. Depending on the plate used, which always contained a control quartz for the mother frequency, it was possible to have a system with 289 lines/25 Hz or 267 lines/30 Hz. The experiments described here are restricted to the 267 line/30 Hz system because of its clear superiority and because of the fact that it will probably be accepted for the videophone transmission.

6.2.2. Cameras

Two semiprofessional Plumbikon cameras built by Philips (Type BL 8011) were available for the experiments with the control unit EL 8016. The camera planned for 625 line operation was also fitted with an electronic viewfinder.

According to the data of the manufacturers, the fully transistorized camera is suitable for operation with television systems in the range between 405 and 819 lines and with 50 or 60 half-images/second. Considering this very wide range in /24 design, we were hopeful that these cameras could also be operated with the 267 line/30 Hz standard. This assumption was verified. The camera produced a very satisfactory image using this scanning standard after slight adjustments of image width and height, as well as image linearity. This proves that the cameras for industrial television can be manufactured with appropriate design features, so that they can be operated at 625 lines/50 Hz as well as with 267 lines/60 Hz using the corresponding cadence generators.

6.2.3. Monitors

Monitors had to be available for the experiments with 267 lines. Their horizontal deflection part had to be designed for a line frequency of 8 kHz. The first experiments were carried out using the Monitor Ev 35 (Fernseh-GmbH) which later on was used as the control monitor (viewfinder) for the 267 line camera. Two monitors from Fernseh GmbH were used for the comparison experiments with 59 cm image screen diagonal distance. One of them was modified for operation at 8 kHz line frequency. The appendix contains data regarding the conversion of the line in stages. The increased image frequency could be adjusted by means of the provided control unit.

All of the synchronization circuits in the monitors operated perfectly without any modifications, even though the signal of the 267 line cadence generator did not have any equalization pulses and also the H synchronization signal did not continue during the vertical scanning in the form of a so-called inverted pulse. In the case of the directly synchronized monitor Ev 35, when operating with BAS signals, this only led to a confused noise in the line transformer, but it was not important for the image holding.

Summarizing, we may establish that the mass produced /25 monitors could be converted to the other line standard with relatively small circuit changes, which would hardly be noticeable if this was done on a large scale. This refutes, once and for all, the opinion that scanning standards different from the normal one are associated with high costs.

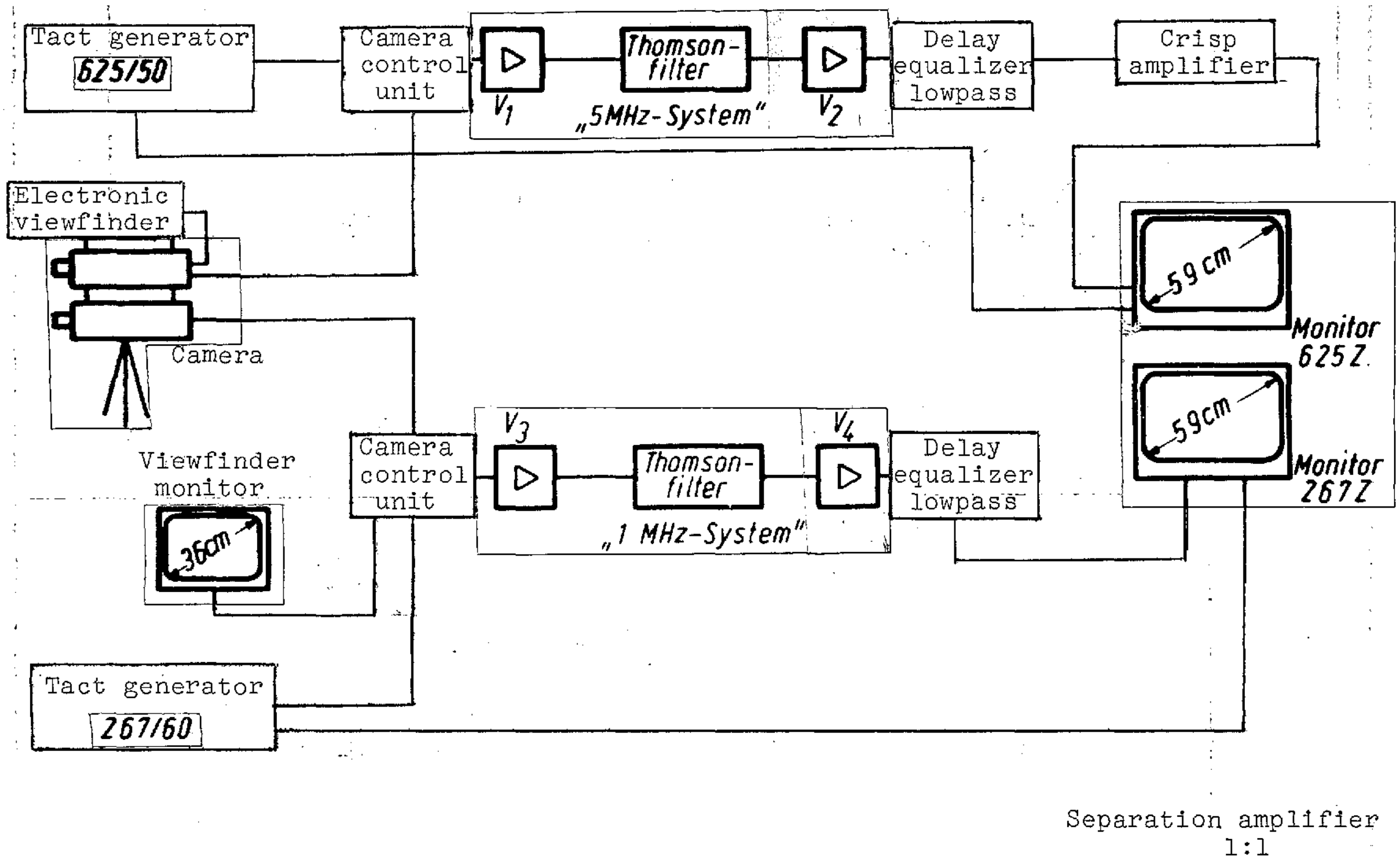


Figure 6. Test installation for TV transmission with reduced bandwidth.

In the various experiments, it was very important that the background brightness of the monitors remained unchanged. Therefore, one should really have used devices with scanned black-white control. In order to reduce the disturbing influences, BA signals and foreign synchronization were used, because in this case it is possible to avoid displacements of the working point caused by changes in the magnitude of the synchronization signal.

7. Experimental Results

The experimental results with the devices described are divided into two groups:

a) data in the form of measurements (oscillogram photographs 1 — 4 for each series) for the various transmission options using comparable representation

b) by means of television screen photographs (Figures 5 and 6 of each series).

This data is not at all sufficient for a conclusive evaluation of the performance capacity of these television transmission systems. The motion information is not contained in the photographs of the image screen, and conclusive evaluations are made more difficult by any further deterioration. In particular, because of the required exposure times, it seems as though the line structure is irradicated more than would be expected according to the sharpness of photographic reproduction.

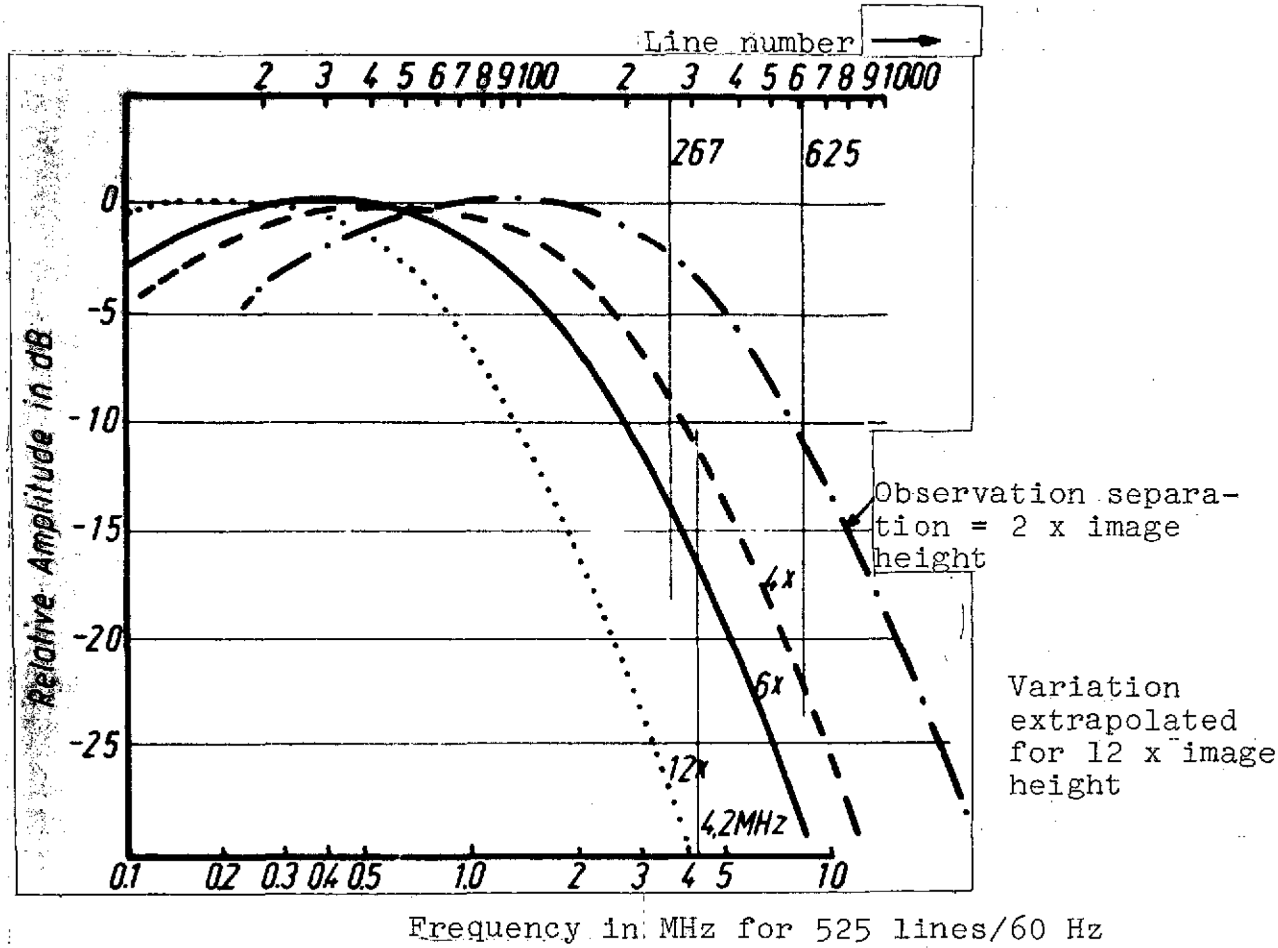


Figure 7. The human eye as a lowpass filter (according to K. Sadashige [6]).

7.1. System Comparison by Means of Measurements

The attached figures show five series of various transmission methods which are compared in the following image screen photographs. We were able to make use of the fact that the writing rate of the electron beam is about 1/2 for the 267 line system as it is for the 625 line system. This means that a certain signal, for example a rectangle with a duration of 2 μs, which has a width of n mm on the image screen of the 625 line monitor, will have a width of about n/2 on the image screen of the 267 line monitor. In order to have the same size image of a bar on /26 the image screen, the rectangular signal would have to have twice the length in time. Since the pulse reproduction is primarily important for evaluating the resolution, we have presented the pulse response for the 2T-$\sin^2$ pulse and the T jump for the 625 line system. Correspondingly, for the 267 line system, a $\sin^2$ pulse with a half value width of 0.4 μs and a jump signal with a rise time of 0.2 μs was used, and half the scale was used in the presentation, so that the corresponding measurement signals have the same width for no distortion on the image screen of the oscillograph. We must consider the fact that the $\sin^2$ pulse with a half value time of 0.4 μs is justified as far as the beam velocity is concerned, but that a communication system with a bandwidth of 1 MHz can only transmit a $\sin^2$ pulse with the half value duration of 1 μs in an undistorted way. This corresponds to a jump signal with τ_s = 0.5 μs. These values would have been appropriate for a measurement comparison referred to frequency bandwidth. However, for an evaluation of the expected picture quality, they are not as suited. The most important measured values of the channels considered are indicated in the corresponding oscillograph photographs.

From the jump response to the 2T $\sin^2$ pulse and for the 625 line system limited to a bandwidth of 1 MHz, one can primarily see that image details corresponding to this pulse do not completely vanish but that they do have a considerably reduced contrast. The clearly visible echoes in the photograph 3-5 (top) can already be predicted from the corresponding $\sin^2$ pulses (Photograph 3-1). The measurements with the 1 MHz bandwidth (series 3, 4, and 5) clearly show the superiority of the low-line system. According to the measured signals, there is a better representation of the details and a better edge sharpness to be expected. The relatively strong overshoot which is /27 produced for the non-shaped $\sin^2$ pulses which do not have a delay distribution correction for the 267 line system, cannot be seen at all in the figure (Photograph 3-5, bottom). Instead, it contributes to a certain plasticity of the image.

7.2. Image Screen Photographs

In order to describe the practical usefulness of the transmission systems considered here, we prepared image screen photographs for two sample images, which can be considered to be typical. One of the photographs (Photograph -5 of each series) consists of a table with a line drawing and handwriting, and a portrait. This is the situation which often occurs in educational television. The other picture (photograph -6 of each series) is concerned with a landscape, which would occur during observation of traffic. Images to be compared were taken in parallel, so as to obtain a direct comparison between the band-limited 625 line system and the 267 line system. This means that the unavoidable motion unsharpness, for example caused by motion of the trees in the wind, is the same in both transmissions. The three image series with the 1 MHz bandwidth (3, 4, 5) are preceded by a picture series with the flow bandwidth (1) as well as another sequence with a slightly restricted bandwidth (2). Two remarks must be made regarding series 1:

a) Photographs 1-1 and 1-2 should represent the 5 MHz transmissions and are not exactly valid for the upper image photographs in photographs 1-5 and 1-6.

b) We do not mean to imply that these screen photographs are the maximum possible quality which can be achieved using the bandwidth 5 MHz. /28

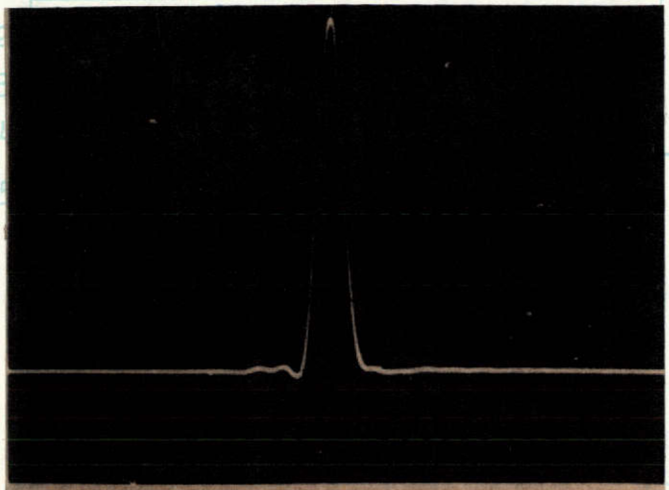


Figure 1.1.
Negative No.:(Polaroid)
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 0.5 μs
625/50

Sin^2 pulse, τ_h = 0.2 μs

Lowpass f_0 x 5 MHz (from Siem, TM)

Thomson filter: none

h_p = 100%

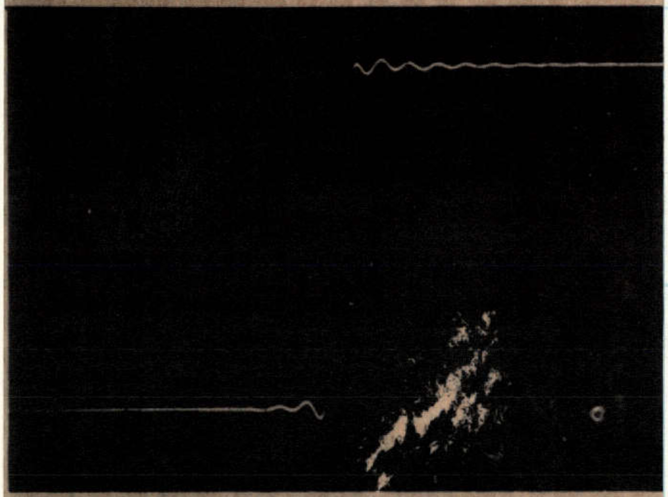


Figure 1.2.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 0.5 μs
625/50

Jump signal τ_s = 0.1 μs

Otherwise like Figure 1.1

τ_s = 0.12 μs

Maximum undershoot: -2%

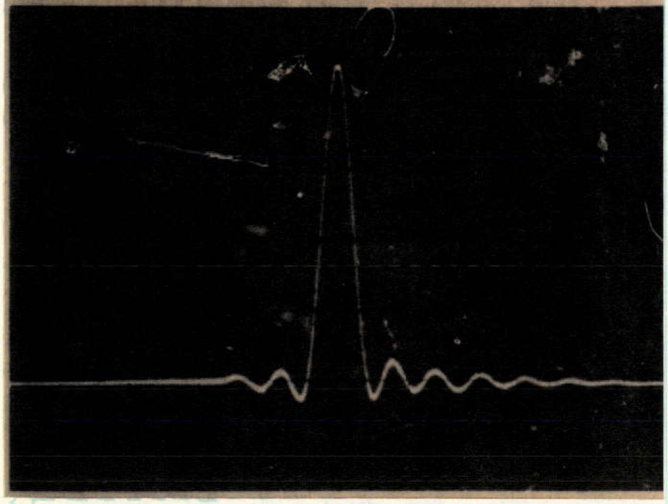


Figure 1.3.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 1 μs

267/60

Sin^2 pulse, τ_h = 0.4 μs

Lowpass f_0 = 1.63, f_n = 1.83 MHz

Thomson filter: none

h_p = 89%

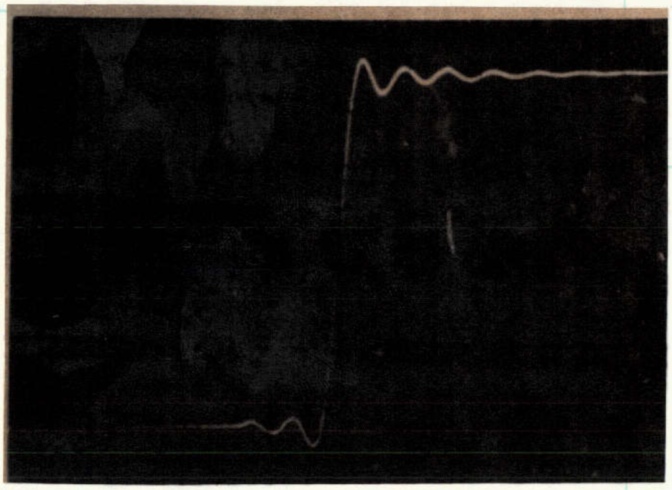


Figure 1.4.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 1 μs

267/60

Jump signal τ_s = 0.2 μs

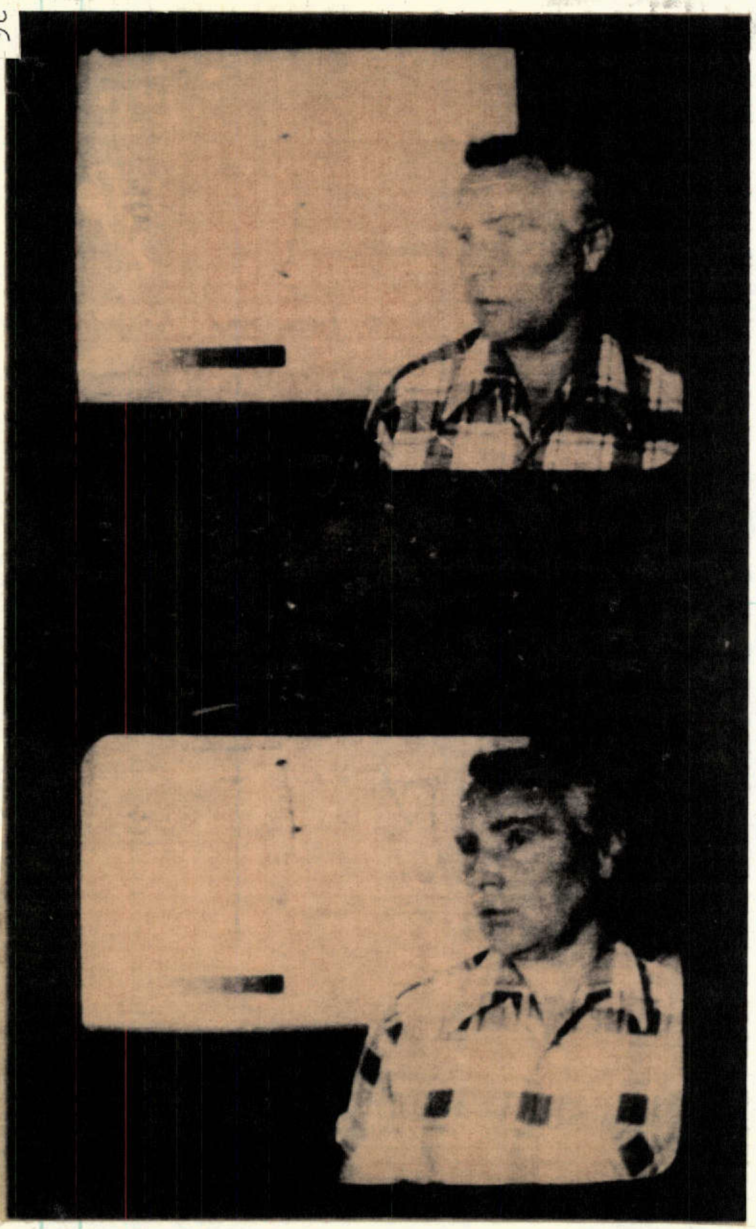
Otherwise like Figure 1.3.

τ_s = 0.32 μs

Maximum undershoot: -4.4%

The second series was recorded because from this it can be estimated that the 267 line system has approximately the same resolution as a 625 line system restricted to about 1/2 of the bandwidth. However, it does require less bandwidth. In order to evaluate the screen image photographs, we must say that the image screens show the line structure more clearly when they are directly observed than can be expressed by the photographs. In the photographs, for which a considerably longer integration time is required than is the case for the eye, the line structure is washed out because of the continuous motion of the half-image rasters with respect to each other.

Finally, we would like to discuss some features which cannot be verified by still photography. This concerns primarily the advantages of selecting approximately 30 images/seconds for the image change number of the low-line system. This reduces not only the shimmering of bright image parts, but also the shimmering of very bright lines. Also, the intermediate line shimmering and the line migration are reduced so much that the line structure has only a small disturbing effect, even though



625/50

Lowpass:
none

Thomson filter:
none

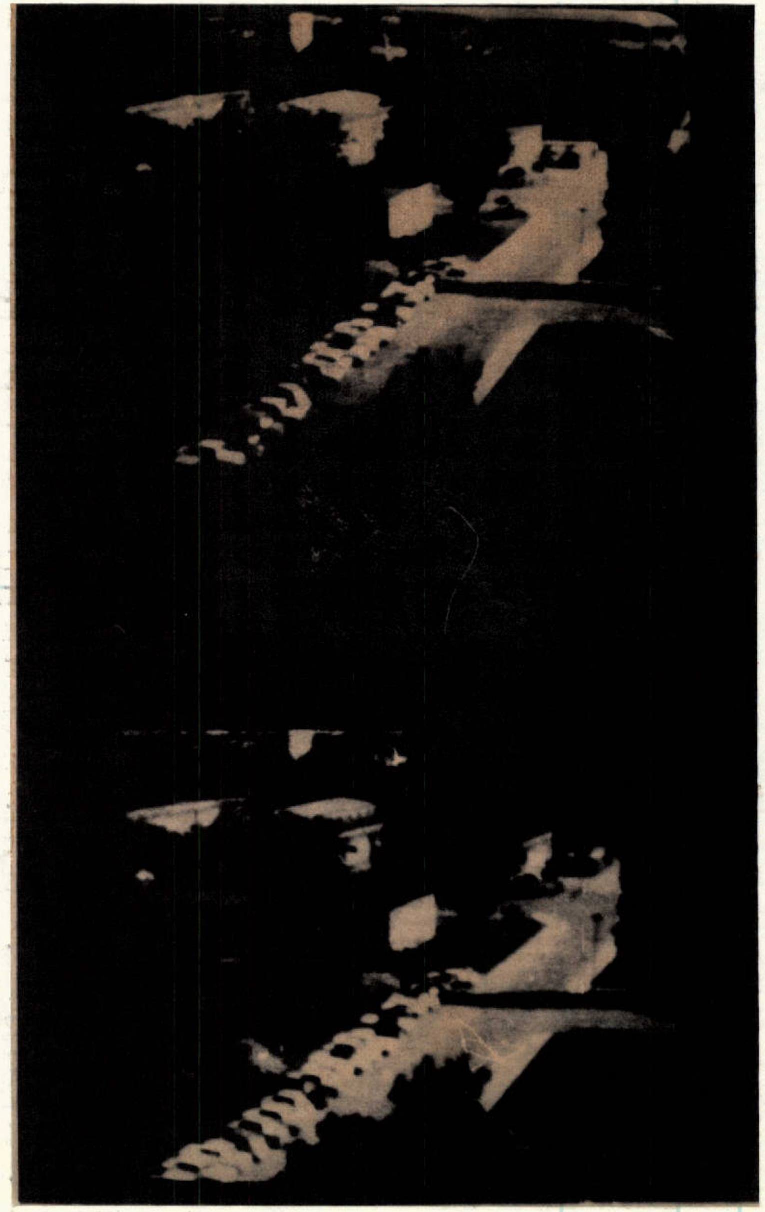
Figure 1.5

Figure 1.6

267/60

Lowpass:
f_0=1.63 MHz
f_4=1.83 MHz

Thomson filter:
none



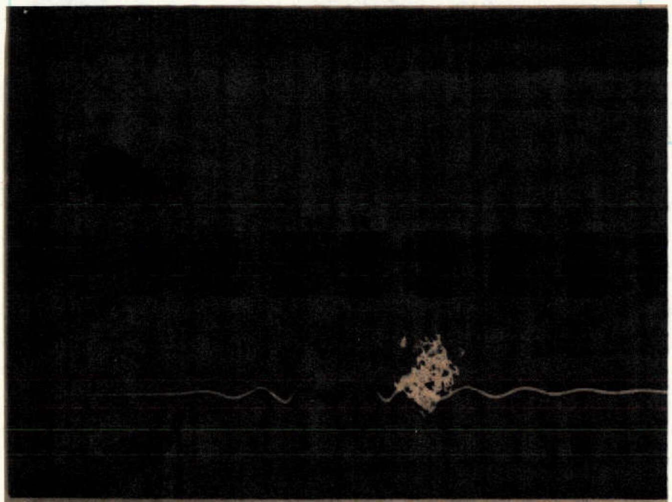


Figure 2.1.
Negative No.: (Polaroid)
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 0.5 μs

625/50

$\sin^2$ pulse, $\tau_h = 0.2$ μs

Lowpass $f_0 = 2.47$ MHz, $f_4 = 2.75$ MHz

Thomson filter $\tau = 0.23$ μs,
$f_p = 2.2$ MHz

$h_p = 70\%$

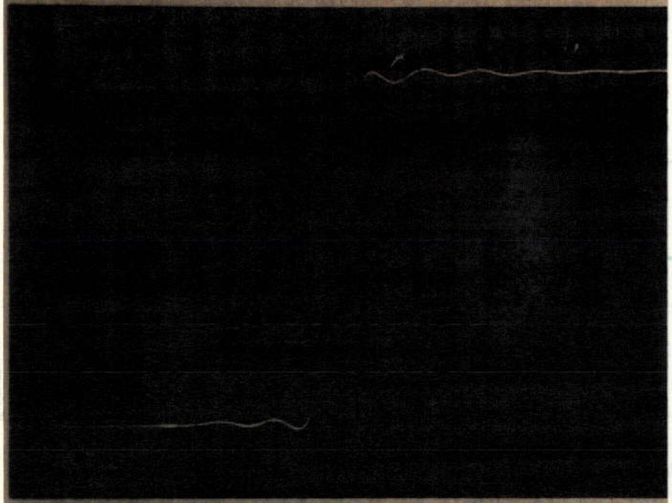


Figure 2.2.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 0.5 μs

625/50

Jump signal, $\tau_s = 0.1$ μs

Otherwise like Figure 2.1.

$\tau_s = 0.26$ μs

Maximum undershoot: -2%

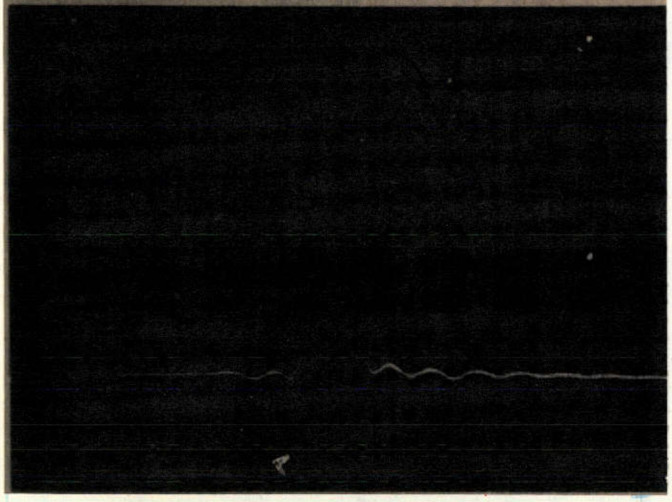


Figure 2.3.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 1 μs

267/60

$\sin^2$ pulse, $\tau_n = 0.4$ μs

Lowpass $f_0 = 1.63$ MHz, $f_4 = 1.83$ MHa

Thomson filter $\tau = 0.34$ μs
$f_p = 1.47$ MHz

$h_p = 74\%$

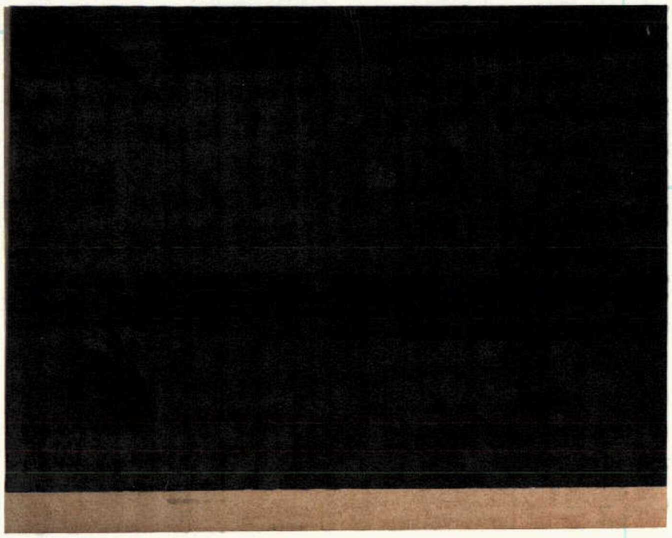


Figure No. 2.4.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 1 μs

267/60

Jump signal τ_s = 0.2 μs

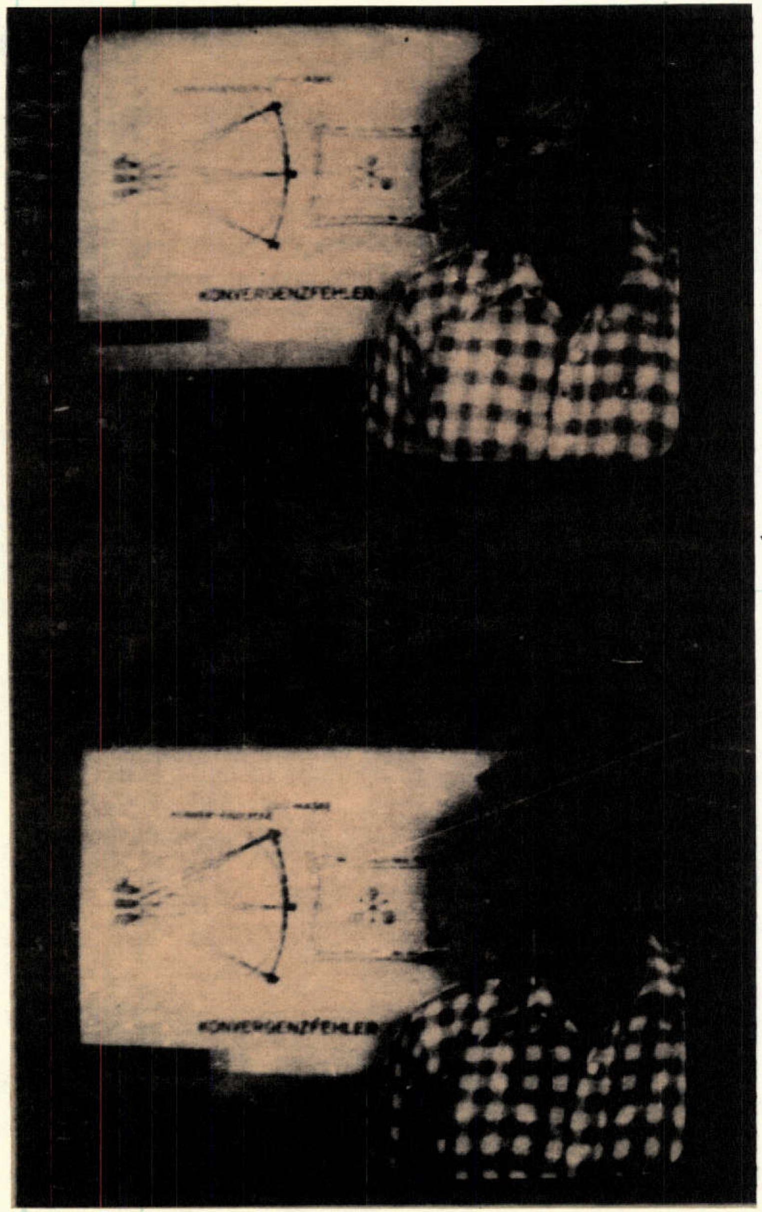
Otherwise like Figure 2.3

τ_s = 0.42 μs

Maximum undershoot: -1.5%

it is clearly observable when observations are made at a distance of about 6 times the image height. Even though it may seem contradictory to select a higher image change number than before using a system with extremely low bandwidth, the advantages of doing this are so great that a more detailed investigation would undoubtedly have verified that the 267 line/60 Hz system is superior to the 289 line/50 Hz system.

It would be very advantageous to carry out experiments with the 267 line/60 Hz system using new methods for reducing the line structure. We must mention the method of Hilborn /29
and Stevenson [27] which is supposed to bring about a considerable improvement in the readability of writing. The application of more modern methods for stabilizing the intermediate line (for example, [28]) would reduce the disadvantages of the line jump method and would make it possible, by using digital circuit technology methods, to again test the idea of moving the raster back and forth by 1/2 a line separation using an additional rectangular voltage (see [1], p. 248 ff.). These experiments could not be carried out within the framework of this research task.



625/50

Lowpass:

f_0=2.47 MHz

f_4=2.75 MHz

Thomson filter:

τ=0.23 μs

f_p=2.2 MHz

Figure 2.5

Figure 2.6

267/60

Lowpass:

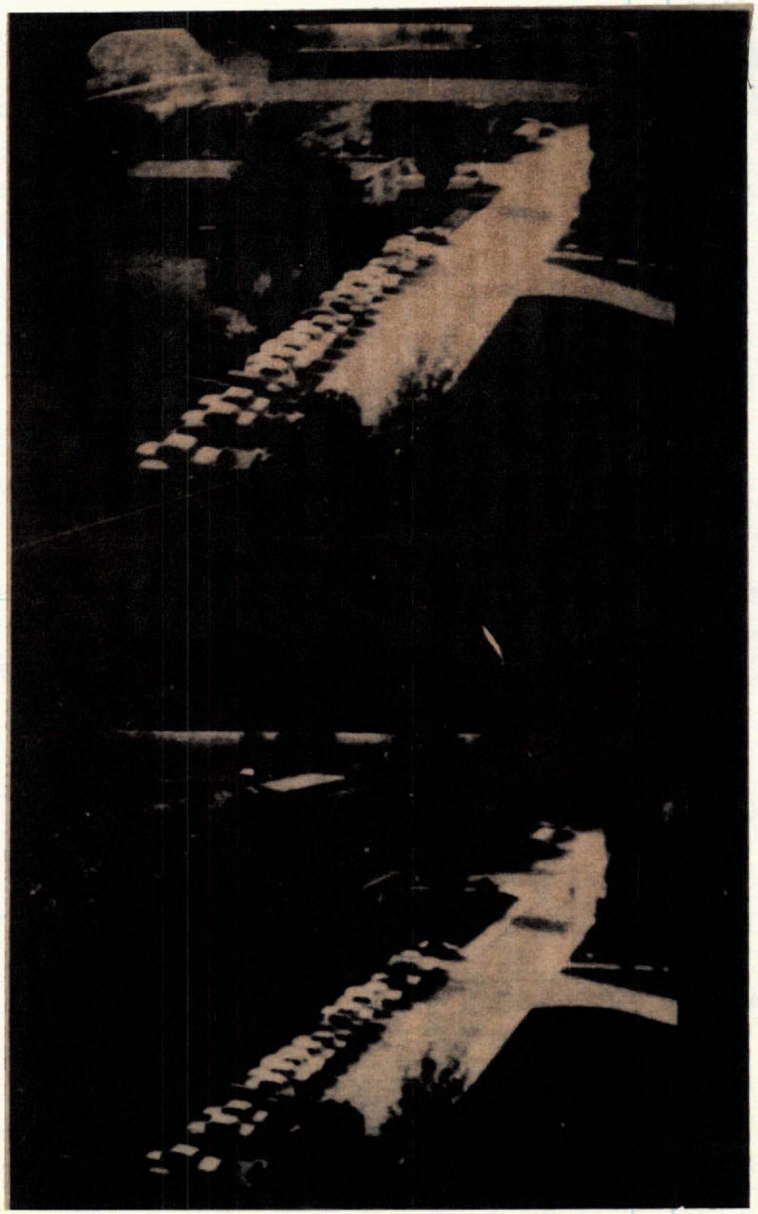
f_0=1.63 MHz

f_4=1.83 MHz

Thomson filter:

τ=0.34 μs

f_p=1.47 MHz



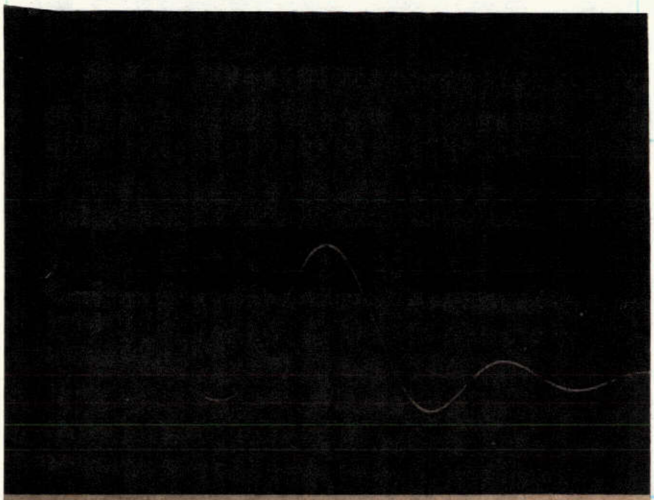


Figure 3.1.
Negative No.: (Polaroid)
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 0.5 μs

625/50

Sin^2 pulse, $\tau_h = 0.2$ μs

Lowpass $f_0 = 1.0$ MHz, $f_4 = 1.1$ MHz

Thomson filter: none

$h_p = 38\%$

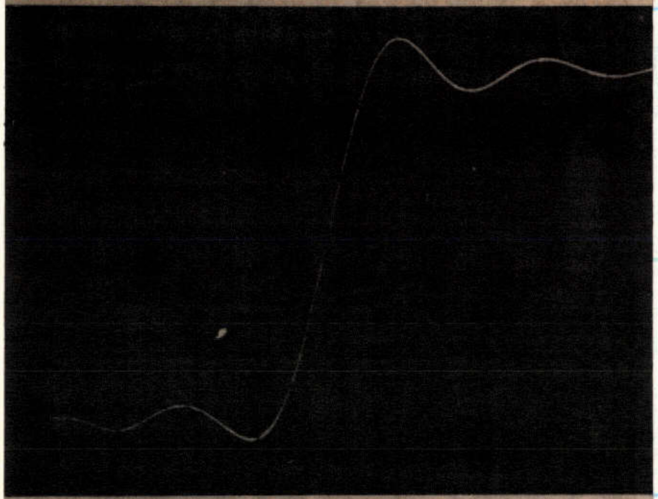


Figure 3.2.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 0.5 μs

625/50

Jump signal, $\tau_s = 0.1$ μs

Otherwise like Figure 3.1.

$\tau_s = 0.47$ μs

Maximum undershoot: -5%

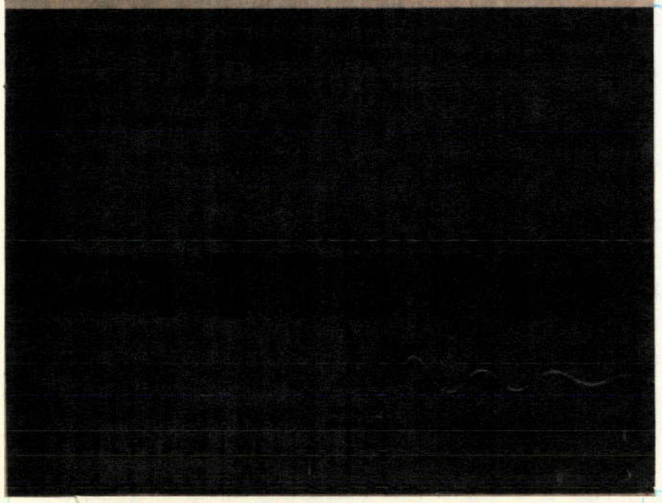


Figure 3.3.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 1 μs

267/60

Sin^2 pulse, $\tau_n = 0.4$ μs

Otherwise like Figure 3.1.

$h_p = 68\%$

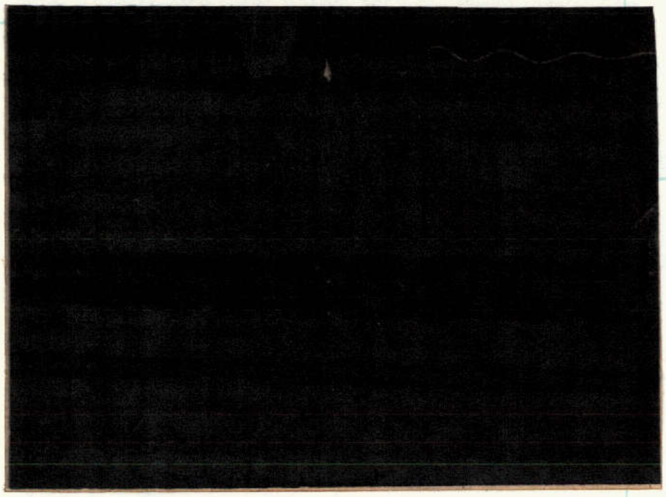


Figure 3.4.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 1 µs

267/60

Jump signal, $\tau_s = 0.2$ µs

Otherwise like Figure 3.1.

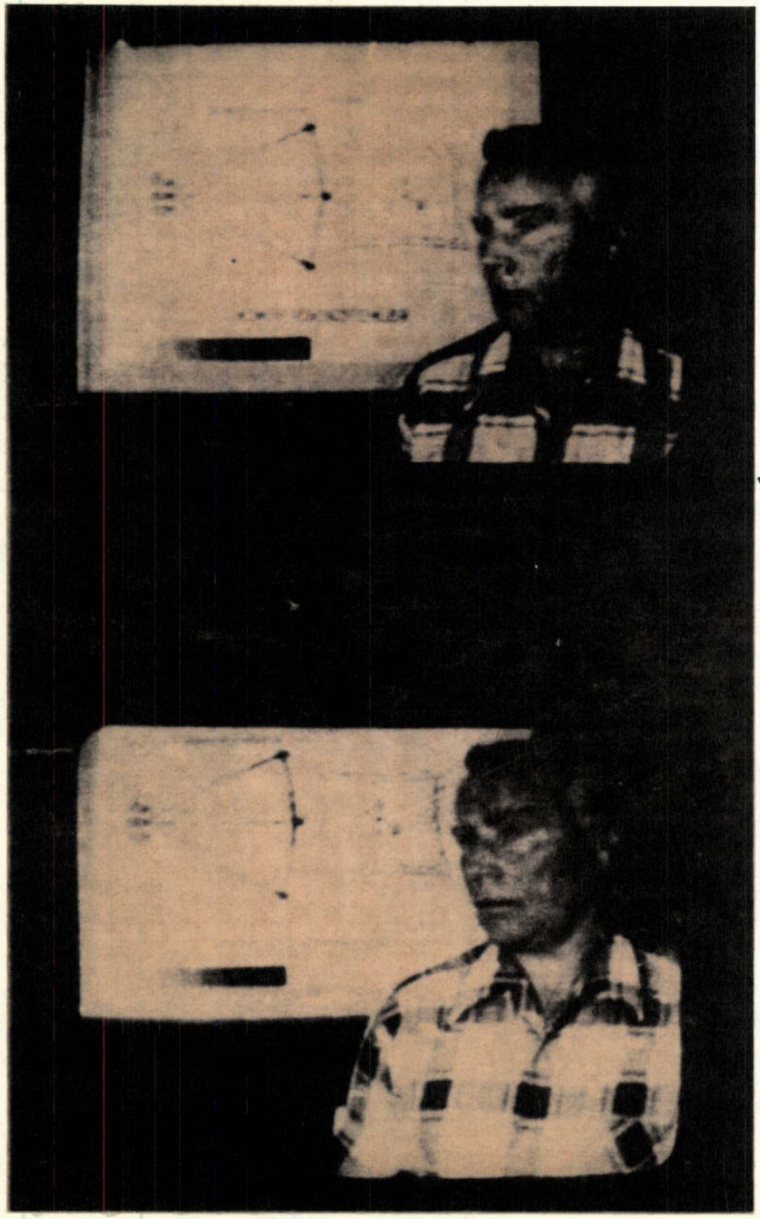
$\tau_s = 0.46$ µs
Maximum undershoot: -4%

8. Conclusions

The preceding results lead to the following conclusions, with the restriction of subjective evaluation tests yet to be performed:

a) Even when the bandwidth of 625 line images is extremely reduced, it is still possible to extract essential information from such images. The screen image photographs show that, when the bandwidth is limited to 1 MHz and the transmission is good otherwise, it is possible, for example, to definitely identify persons. In a countryside image, it is possible to recognize the essential elements, such as buildings, vehicles, roads, etc., to a sufficient degree. In certain situations, it will be quite appropriate to carry out such transmissions.

b) We are certain that, for a given bandwidth of about 1 MHz, a transmission method using 267 lines and 60 half-images/second represents a much better solution than the



625/50

Lowpass:
f_0=1.0 MHz
f_4=1.1 MHz

Thomson filter: none

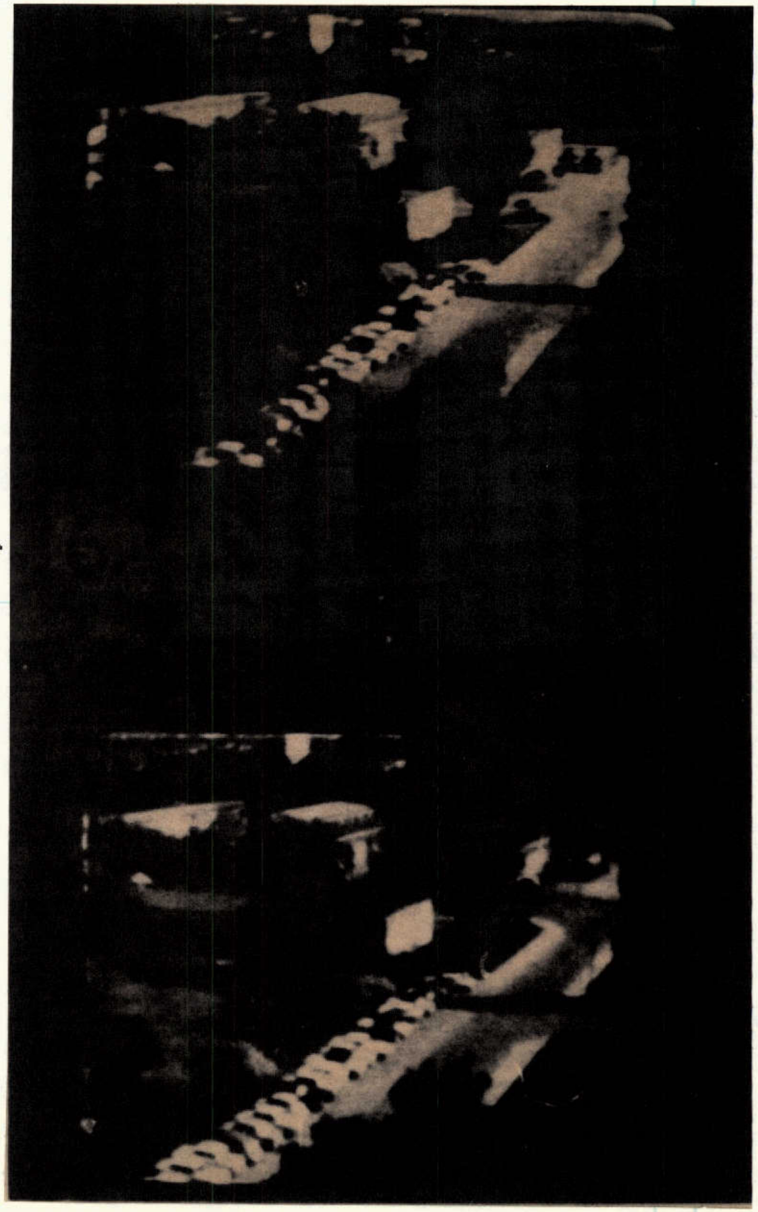
Figure 3.5

Figure 3.6

267/60

Lowpass: like above

Thomson filter: none



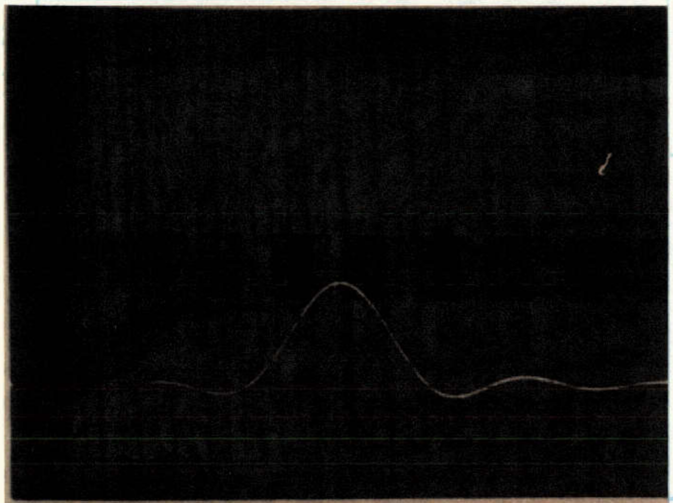


Figure 4.1.
Negative No.: (Polaroid)
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 0.5 μs

625/50

$\sin^2$ pulse, $\tau_h = 0.2$ μs

Lowpass $f_0 = 1.0$ MHz, $f_4 = 1.1$ MHz

Thomson filter: $\tau = 0.57$ μs
$f_p = 0.88$ MHz

$h_p = 30\%$

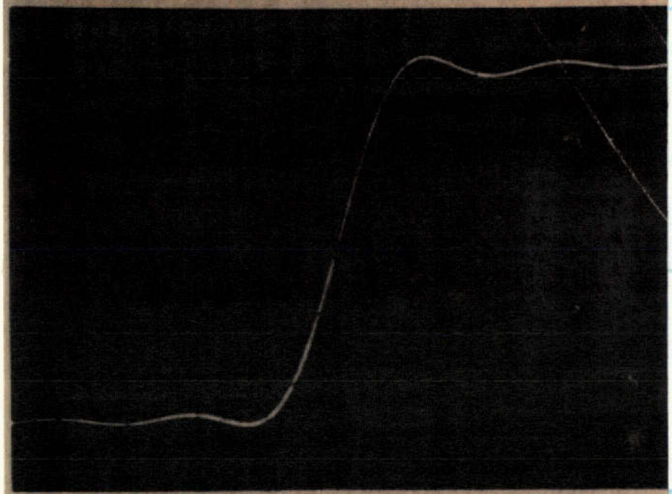


Figure 4.2.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 0.5 μs

625/50

Jump signal, $\tau_s = 0.1$ μs

Otherwise like Figure 4.1.

$\tau_s = 0.62$ μs

Maximum undershoot: -2%

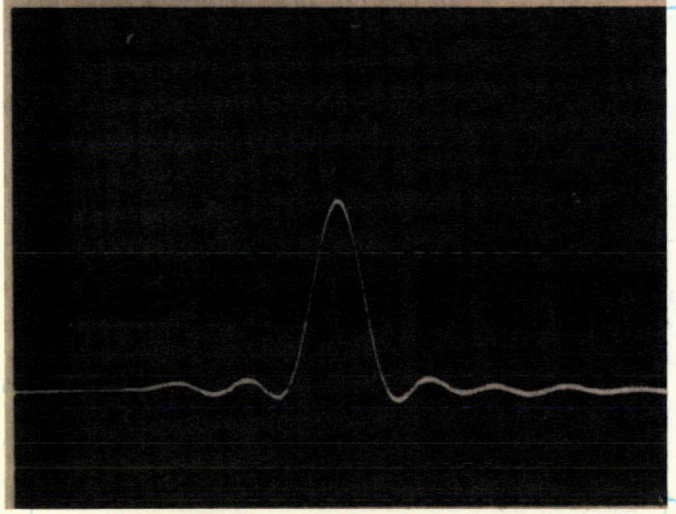


Figure 4.3.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 1 μs

267/60

$\sin^2$ pulse, $\tau_h = 0.4$ μs

Otherwise like Figure 4.1.

$h_p = 53\%$

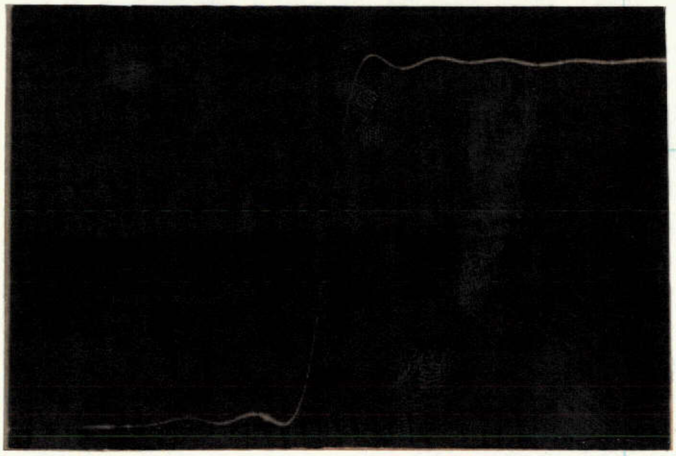


Figure 4.4.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " 1 μs

267/60

Jump signal, τ_s = 0.2 μs

Otherwise like Figure 4.1.

τ_s = 0.63 μs

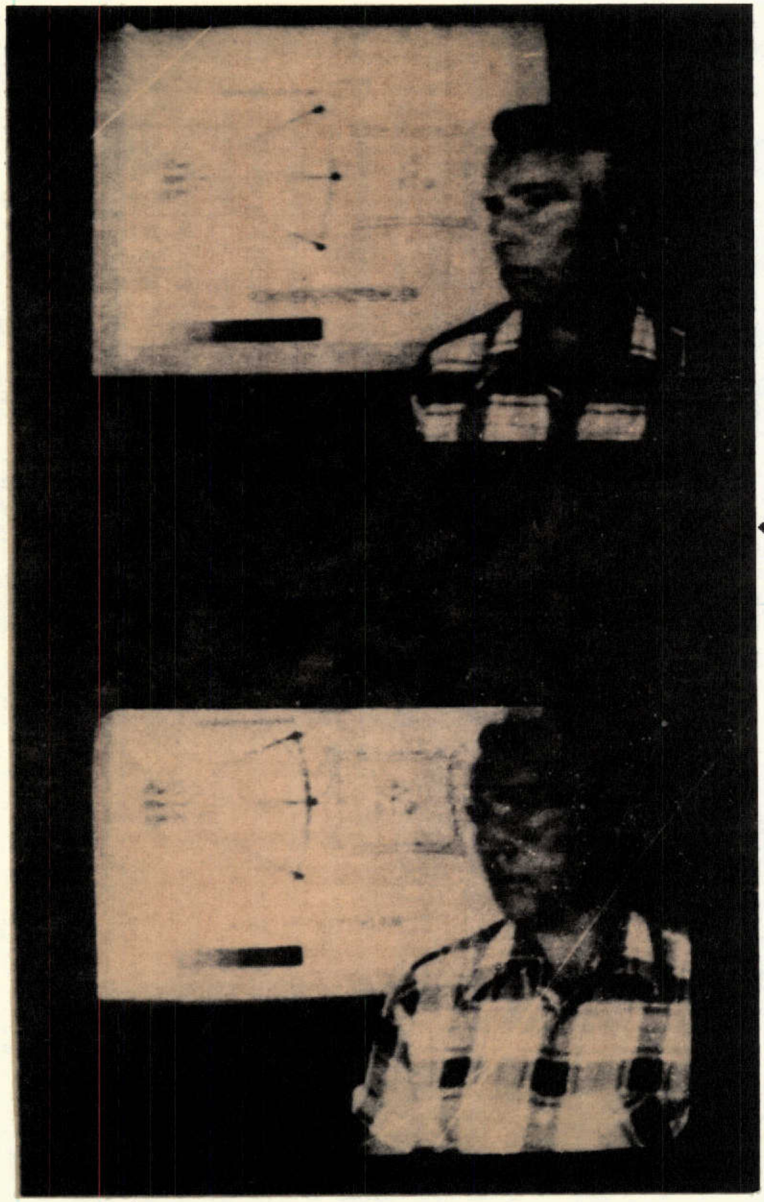
Maximum undershoot: -2%

corresponding band-limited 625 line image. When observations are made from a distance of more than 10 times the image height, there is effectively no difference in image quality compared with the 625 line image with the complete bandwidth.

When observations are made from a small distance, the line structure can be observed but usually it is not disturbing and, in particular, it does not bring about eye fatigue. For industrial television or non-public television, we believe that a bandwidth of 1 MHz is sufficient. In most cases, a sufficient detailed resolution can be provided by a corresponding selection of the image angle. /30

c) When a frequency raster is established for non-public television, a video bandwidth of 1 MHz should be assumed.

d) The 1 MHz communication technique now in development for picturephone for local traffic could be applied to industrial television installations during the testing period.



625/50

Lowpass:
f_0=1.0 MHz
f_4=1.1 MHz

Thomson filter:
τ=0.57 μs
f_p=0.88 MHz

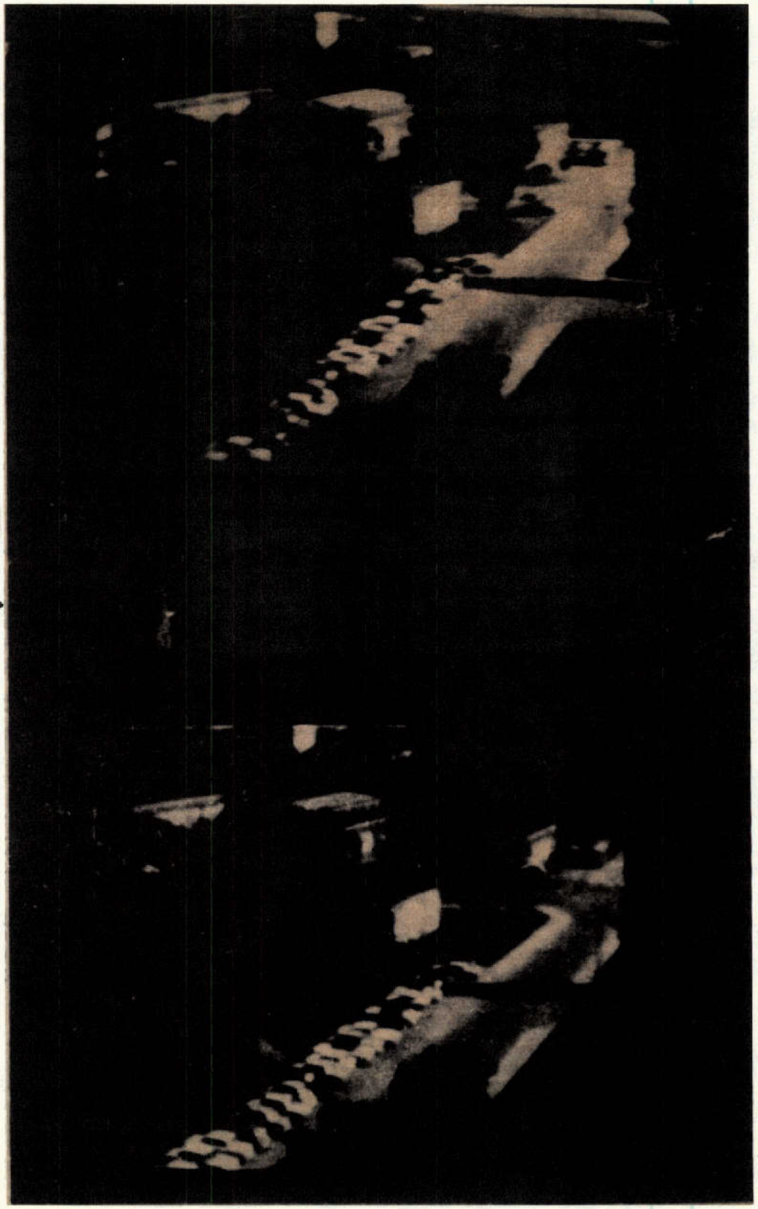
← Figure 4.5

Figure 4.6 →

267/60

Lowpass:
like above

Thomson filter:
like above



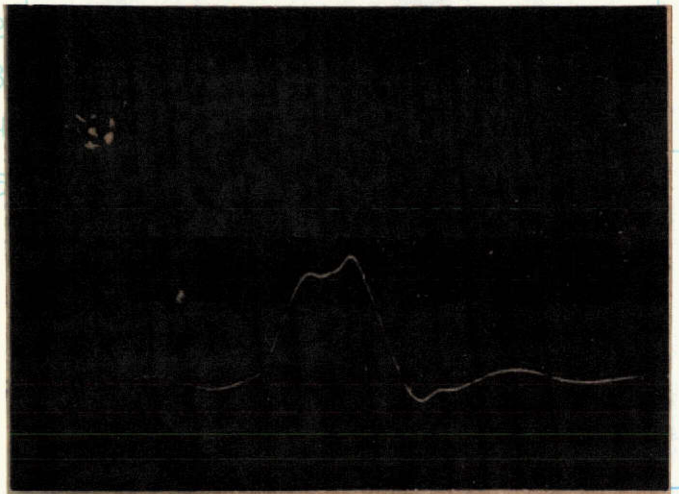


Figure 5.1.
Negative No.: (Polaroid)
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 0.5 μs

625/50

$\sin^2$ pulse, τ_h = 0.2 μs

Lowpass f_0 = 1.0 MHz, f_4 = 1.1 MHz

Thomson filter: τ = 0.57 μs
f_p = 0.88 MHz

with "crispening"

h_p = 34%

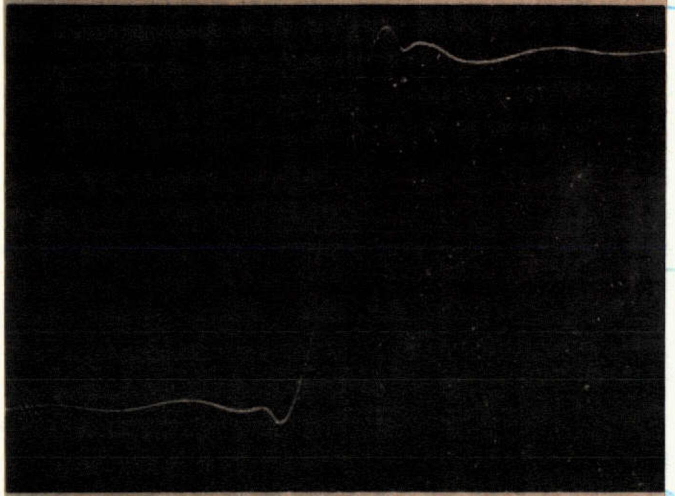


Figure 5.2.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " t0 0.5 μs

625/50

Jump signal, τ_s = 0.1 μs

Otherwise like Figure 5.1.

τ_s = 0.4 μs

Maximum undershoot: -2%

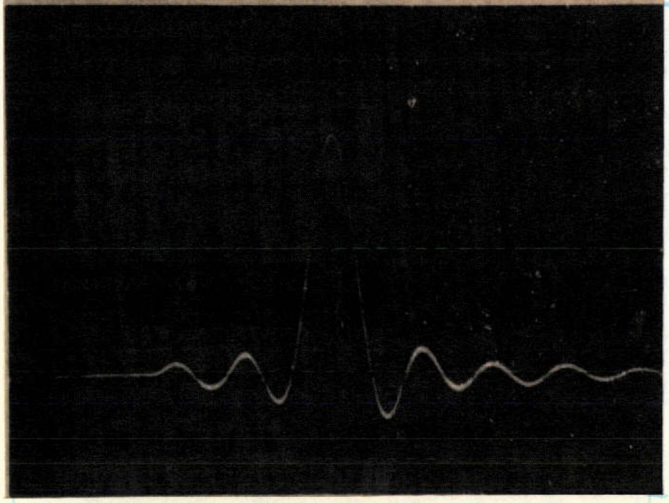


Figure 5.3.
Negative No.:
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 1 μs

267/60

$\sin^2$ pulse, τ_h = 0.4 μs

Lowpass f_0 = 1.0 MHz, f_4 = 1.1 MHz

Thomson filter: none

h_p = 67%

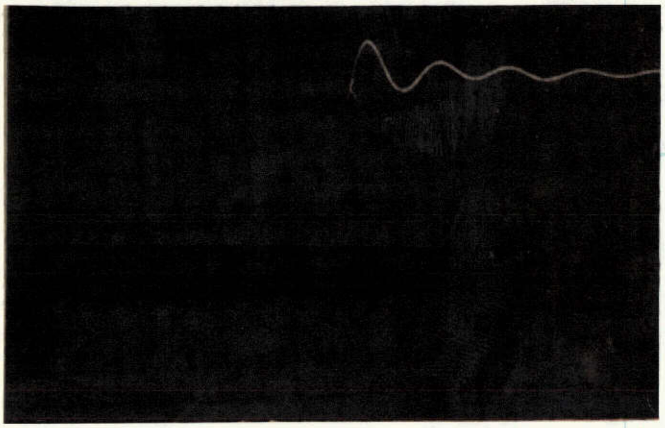


Figure 5.4.
Negative No.
Raster:
Vertical: 1 cm corresponds to 20%
Horizontal: 1 cm " to 1 µs

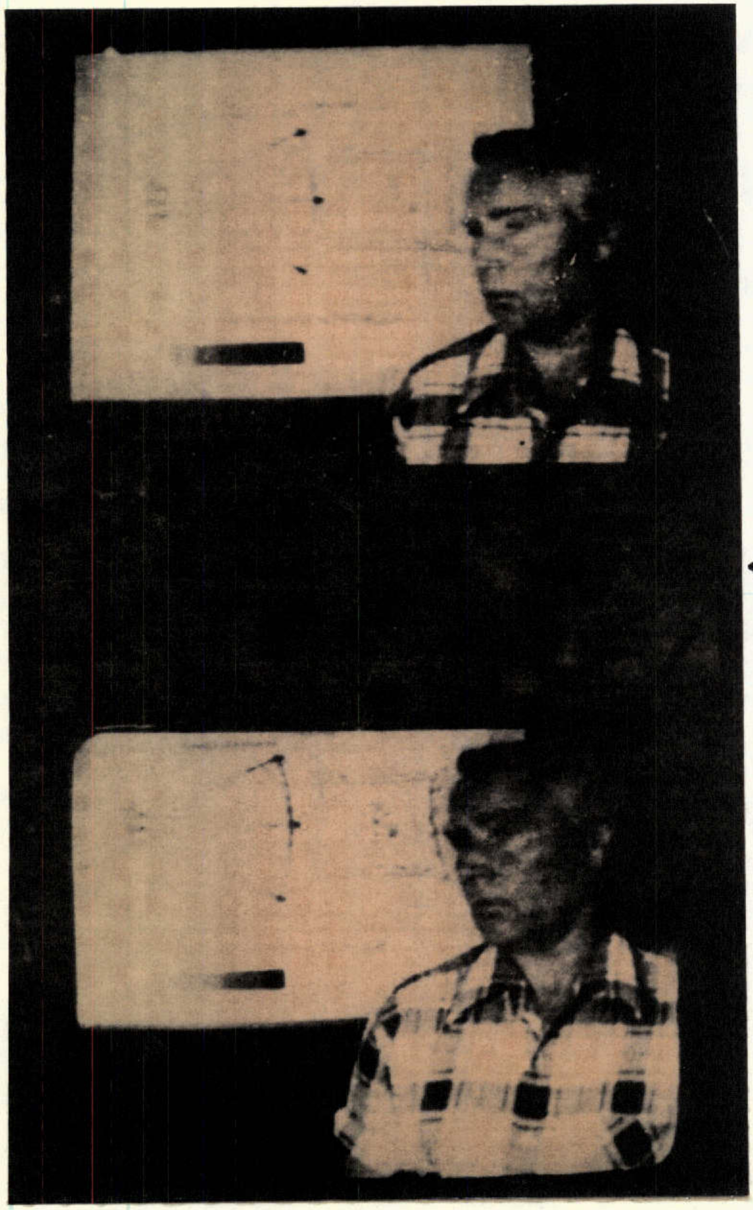
267/60

Jump signal, $\tau_s = 0.2\ \mu s$

Otherwise like Figure 5.3.

$\tau_s = 0.48\ \mu s$

[Illegible]



625/50

Lowpass:
f_0=1.0 MHz
f_4=1.1 MHz

Thomson filter:
τ=0.57 µs
f_p=0.88 MHz
with "crispening"

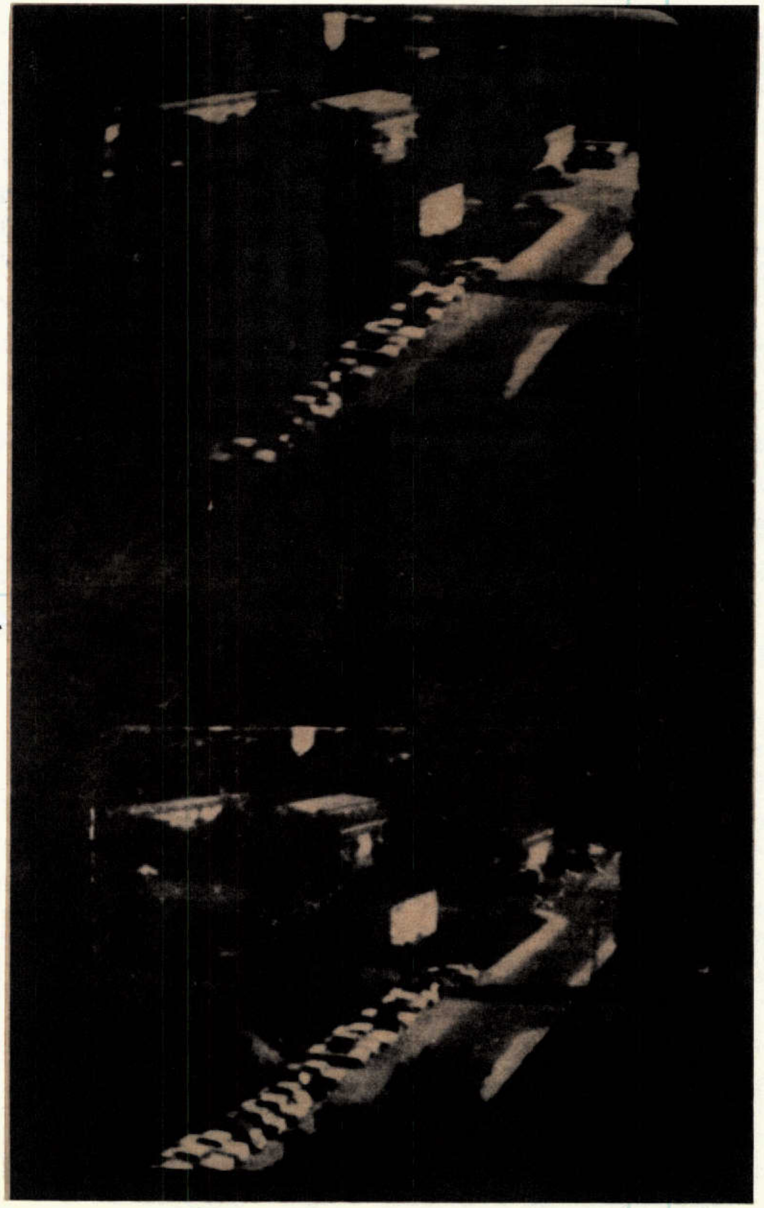
← Figure 5.5

Figure 5.6 →

267/60

Lowpass:
like above

Thomson filter:
none



APPENDIX 1

ADJUSTMENT OF THE HORIZONTAL DEFLECTION CIRCUIT OF IMAGE REPRODUCTION DEVICES TO THE LINE FREQUENCY OF 8 kHz /31

The modification of monitors to the 267 line standard was connected with some difficulties. The first experiments were made using the old Monitor EV 35 with tubes (Fernseh GmbH), which has a self-oscillating sweep for the horizontal deflection and direct synchronization. The line transformer is in the form of a disc winding, which is suitable for changes in the laboratory. There were a number of replacement line transformers available from the manufacturing process, which could be rewound. No experience was available on the dimensioning of horizontal deflection stages and line transformers. The literature in this area usually is restricted to general statements regarding the method of operation of the stages [29, 30]. Line transformers and other deflection devices are primarily made by a number of large special firms, who do not provide the manufacturing of individual items. We did not find it too difficult to recalculate the required line transformers, even though we assumed this would be a major task. Since all the deflection coils were retained, the same deflection current as before could be used for the new line frequencies. For a given Ferrit core of the transformer, the winding which feeds the deflection unit n_3 (see circuit diagram, Figure 1) and its number of windings only depends on the deflection currents and the inductivity of the deflection coil, but it does not depend on the line frequency. This means that the original winding number could be retained. Since, for this image tube, we

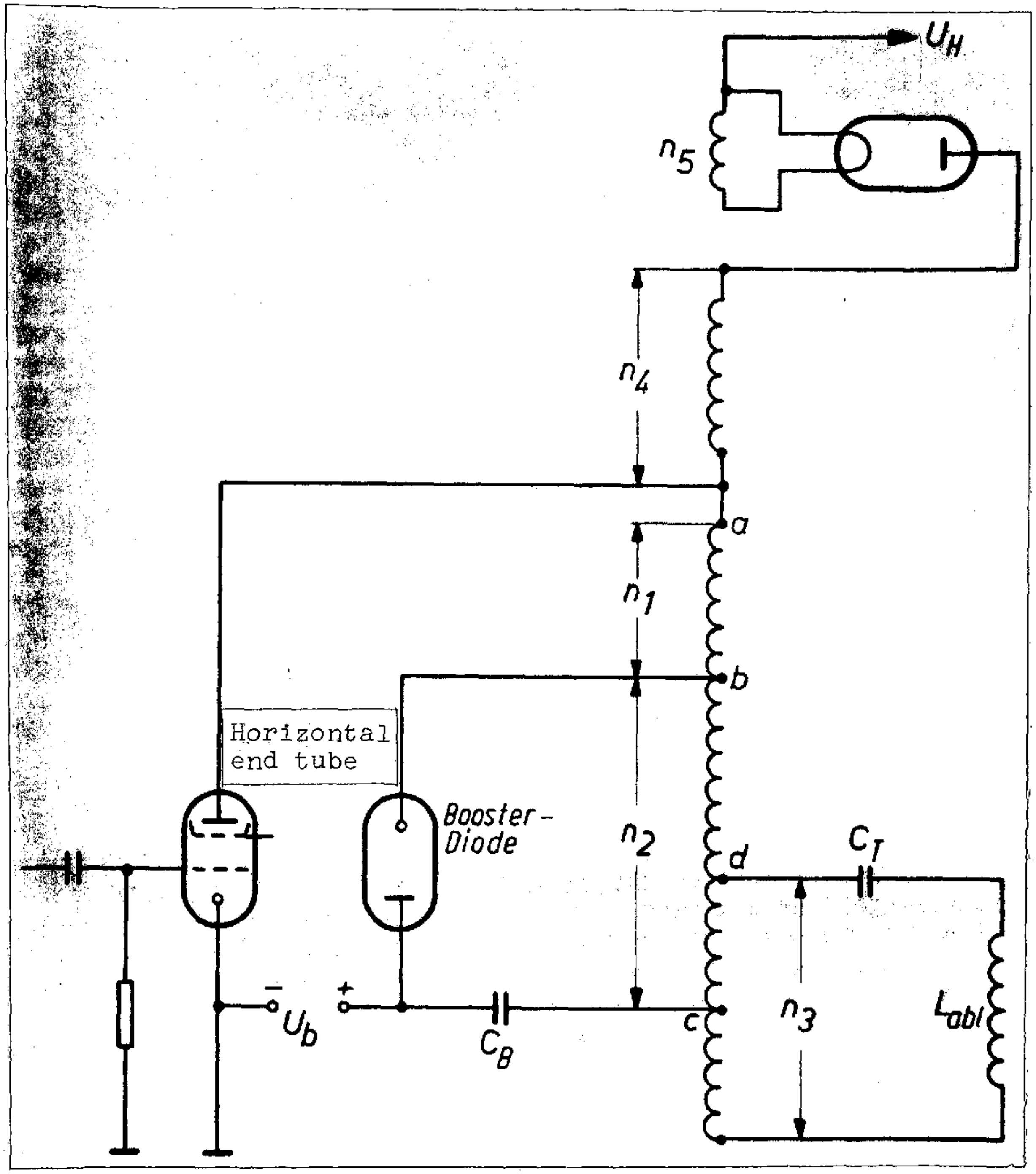


Figure 1 (Appendix). Horizontal end stage, circuit diagram.

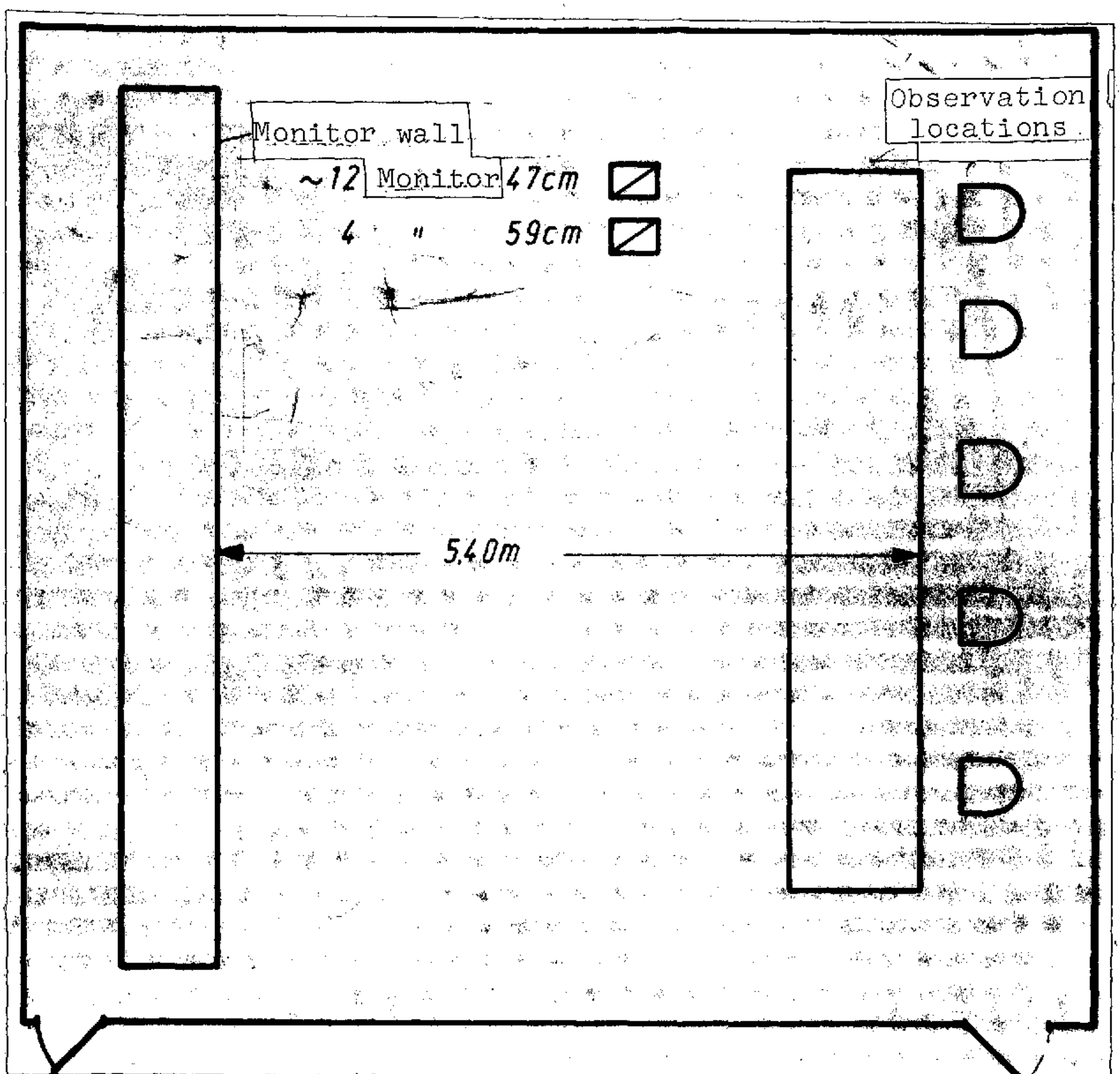
required the same height voltage as before and approximately the same maximum voltage load of the line end tube should result, the transmission ratio $(n_1 + n_2)/n_2$, that is, the connection for the booster diode, can also remain unchanged. The transmission ratio $(n_1 + n_2)/n_3$ must be changed, and considering the approximately unchanged feedback times, they are recalculated to be inversely proportional to the line frequency. The windings n_4 and n_5 are changed by the same ratio. The higher winding numbers could only be achieved using correspondingly smaller wire cross sections on the available winding spools. The increased copper losses were /32 acceptable. In fact, the effective power to be applied to the horizontal deflection stage decreases noticeably. This is expressed by the fact that, when there is deflection over the entire image width and if the correct value of the high voltage is used, a considerably reduced operational voltage is sufficient. Correspondingly, the voltage over the booster condensor is lower, which must be taken into account in parts of the circuit which depend on this. The difference between the available operational voltage and the required one was used for electronic control, in order to obtain the low internal resistance of the current source and to increase the general operational stability of the units.

In the case of a later modified new 59 cm monitor with 110° deflection, it was necessary to adjust the control generator for the deflection part by new windings of the oscillator coil so as to obtain the other line frequency. For this deflection angle, the value of the condensor for tangent distortion correction had to be considerably modified. Other details regarding the modification of the line end stages cannot be given here because of space limitations. The publication by H. Meyer [31] was found to be the best information source.

APPENDIX 2

REMARKS ON TELEVISION INSTALLATIONS FOR TRAFFIC CONTROL OF THE HANNOVER POLICE /33

Television installations which are used every year by the traffic police in Hannover for fair traffic, are a tempting application for a 1 MHz industrial TV installation. Television images taken by fifteen different television cameras at various high density points of traffic are for the most part transmitted to a central point using directional communication links, where they are displayed on monitors. If required, television pictures are taken from helicopters and transmitted on an assigned radio channel at 450 MHz with 7 MHz HF and 3.5 MHz nominal video bandwidth to the central point. Figure 2 of the Appendix gives a summary of the central point structure. The central point has been enlarged many times over the last few years. The present configuration is a consequence of the requirement that up to five observers should be able to simultaneously observer sixteen monitors. As one can see by examining the resolution function of Figure 7, even for the small number of monitors with 59 cm image screen diagonal distance, more than 300 lines cannot be resolved. A "lowpass" with a bandwidth of about 1 MHz is "switched in" to the 5 MHz wide electrical transmission path, in the form of the visual observation path (in the case of two-dimensional observation). Considering the difficulties of making available the frequency space for the radio channel, this state of affairs seems especially absurd.



Minimum observation distance for 59 cm Monitors: 16 x
Minimum observation distance for 47 cm Monitors: 20 x
image height

Figure 2 (Appendix). Traffic observation center, Hannover, test grounds (schematic)

During observations of TV radio transmissions in 1968 and 1969, it was found that the transmission quality was very low for many reasons. Shot, moire disturbances and deficient gradation were the main deficiencies. During an operational intermission, and without any warning, 625 lines/50 Hz television pictures previously recorded on video magnetic tape (Ampex VR 7000) from the helicopter were transmitted to the assigned monitor through filters. This corresponded to a window bandwidth of 2.2 MHz and a pulse bandwidth of 1.75 MHz. Because of band clipping, the subjective noise separation was substantially increased and by a clever selection of the recording and reproduction level of the tape recorder, it was /34 possible to obtain a certain reduction in gradation distortion. It later became known that this was a recording, and the police officials said that the reproduced image was "much better than the original." The insufficient resolution was neither noticed nor complained about.

Many advantages are connected with the use of the 267 line/60 Hz scanning standard for traffic television networks:

— Increased image change frequency would considerably enhance the observation and working conditions at the central point.

— The assignment of radio channels for moving cameras would be made easier.

— The television signals of the fixed cameras could be transmitted through telephone cables using picturephone technology.

— The application of picturephone communication technology would make it possible to arbitrarily switch 30 cameras into 10 monitors using a coupling field, and the associated costs would be low.

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Translated for National Aeronautics and Space Administration under Contract No. NASw-2483 by SCITRAN, P. O. Box 5456, Santa Barbara, California, 93108.